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Terrestrial isopods (Crustacea: Oniscidea) and biogeographical patterns from South-Western Australia

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Terrestrial isopods (Crustacea: Oniscidea) and biogeographical patterns from south-western Australia.

by
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USE OF THESIS

The Use of Thesis statement is not included in this version of the thesis.

ABSTRACT

This thesis examines terrestrial isopod (Crustacea: Oniscidea) diversity and biogeography from south-western Australia, a region already recognised for its exceptional high biodiversity and concentrations of endemic species. A taxonomic investigation of isopods in the Western Australian Museum and material collected systematically as part of this study revealed seventy taxa, sixty of which were considered native species. The thesis provides a comprehensive review of regional taxonomic history and includes a key, complete with a set of forty characters states and taxa, illustrated by a number of photographic plates that are designed for use by specialists and non-specialists alike. Prior to this study all the region's indigenous terrestrial isopods were poorly described and, while many taxa are still to be resolved at the species level, it appears at least 35 species are new to science.

The distributions of indigenous taxa form some clear and consistent biogeographical patterns. Distributions of taxa are influenced by steep rainfall gradients, the seasonality of rainfall and by biophysical characteristics of the landscape including, localised landforms and differing microhabitat utilisation. The region is one of high diversity, with both widely distributed species and highly localised endemics. Two areas, the Perth region of the Swan Coastal Plain and the tall, wet southern forests, are particularly species rich. Beta diversity is also high. This reflects a heterogeneous landscape with profound differences in microhabitat availability, differences often due to recent exogenous disturbance. The construction of a biogeographic model showed a major faunal break, which created northern and southern bioregions to which 68% of the taxa were endemic. This biogeographical boundary is significant in that it had not been recognised in any previous biogeographical schemes.

Data derived from the analysis of soil, leaf litter and log microhabitat samples show that the existence of terrestrial isopods in south-western Australia is intractably related to organic matter. The geographical range of species is often best explained by the types of microhabitat utilised and their degree of moisture dependency. The wetter forests of the region contain relictual short range endemics reliant upon surface organic matter, particularly leaf litter. Moisture is clearly a limiting factor in the distribution of all species. The five most common genera can be differentiated by their dependence upon different moisture regimes in a range of microhabitat types. The spatial and temporal continuity of different types of organic matter in forested landscapes is considered critical to the conservation of the group in south-Western Australia. Land management practices, such as logging and burning, which influence the nature and distribution of organic matter, are likely to induce profound changes in terrestrial isopod communities. Regular and broad-scale prescription burning and the increasing scarcity of large and decayed logs are considered to be a primary threat to their conservation status.

Hypotheses involving the histoncal role of surface organic matter are developed to explain the speciation patterns of the group in the region. In order to test these models, and to provide an urgently needed assessment of the conservation status of relictual forest invertebrates, clear taxonomic prionties are recommended.

DECLARATION

I certify that this thesis does not, to the best of my knowledge and belief:

(I) incorporate without acknowledgement any material previously submitted for a degree or diploma in any situation of higher education;

(II) contain any material previously published or written by a person except where due reference is made in the text; or

(III) contain any defamatory material.

Signature

Date: 4 August 2004

ACKNOWLEDGMENTS

During the course of this work, many people have assisted me in many different ways. Unfortunately, some of these acts of professional and personal benevolence, I am unable to recall. If you are one of the people whose kindness I have overlooked, I can only apologise profusely. There are, of course, always some acts of assistance, or gestures of support, that survive the vagaries of even the most fragile of memories. These, I would like to acknowledge now.

For their commitment, and skill in the art of finding and catching slaters, I would like to thank Kerry Ironside, Leong Koh, Lars Manal and Amy Warner. Without their contribution, the scope of this thesis would have been much restricted. I am greatly indebted to Kerry Ironside who unselfishly gave up many months of her time in order to assist me with all aspects of the project.

My time at the Western Australian Museum was made much easier due to the assistance and great support from Melissa Hewitt. I am also very grateful to Mark Harvey and Julianne Waldock for the loan, and instruction in the use of, the Berlese funnels. Mark Cowan kindly helped with an early analysis of the distributions of south-western Australian Crustacea. This made the task of creating the distribution maps herein much easier. Thanks to Paul van Heurk (CALM), Pierre Horwitz (ECU) and Alex Watson (ECU) for the specimens they kindly donated.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF PLATES

"I do not know whether there is anything particularly exciting in the air of this particular part of Hertfordshire, but the number of engagements that go on seems to me considerably above the proper average that statistics have laid down for our guidance. I think some preliminary enquiry on my part would not be out of place."

Oscar Wilde, *The Importance of Being Earnest*, Act Three.

CHAPTER 1

PATTERNS, PERCEPTIONS AND MOISTURE

1.1. INTRODUCTION

The creation of biogeographic regions has long fascinated scientists (Cox, 2001). The concept of biogeography, the study of the distribution of organisms, is a simple one. Nevertheless, there are many approaches to the subject. With such a diversity of approaches, the recognition of two discrete categories, ecological and historical biogeography, by Myers and Giller (1988) is particularly useful. Ecological biogeography is concerned with processes operating over short temporal and spatial scales while historical biogeography is concerned with evolutionary processes over millions of years on continental or global scales (Crisci, 2002).

Plotting the taxa distributions of taxa is fundamental to the process of biogeographical research. While much recent research has focussed upon biogeography from an ecosystems perspective (Crisci, 2002), recent approaches (e.g. Craw, Grehan & Heads, 1999) have re-emphasised the importance of the geographical dimension of biodiversity and its centrality to our understanding of evolutionary patterns and processes.

From a historical biogeographical perspective, the current spatial arrangement of organisms is thought to be the result of three different processes that have been operating throughout evolutionary time (Crisci, 2002). These are:

1. extinction;
2. dispersal; and
3. vicariance.

The process of extinction refers to the death of all individuals of a local population, a species or higher taxon and there is no debate among biogeographers as to its validity (Crisci, 2002). The other two processes, dispersal and vicariance, have been presented as competing explanations for the current distribution of organisms. The process of dispersal suggests the occurrence of a common ancestor in a geographic centre of origin with later dispersal into areas where descendants survive to the present day. The process of vicariance implies an original widespread distribution of an organism which became fragmented with descendants surviving in isolated pockets until the present day (Crisci, 2002). Fundamentally, both dispersal and vicariant processes involve barriers. Barriers may be physical characteristics of the landscape, climatic elements or ecological factors.

1.2. HISTORICAL BIOGEOGRAPHY

The debate about vicariance and dispersal as mechanisms of speciation and as explanations for the present day distribution of biota can be resolved by the construction of biogeographic model (Craw et al., 1999). This recognizes both as important processes from which the distribution of organisms result. A model can be constructed by the

identification of congruent species distribution patterns. This then allows for the recognition of districts or provinces containing species with similar distributions or which are geographically constrained by common boundaries. The boundaries of biogeographical districts or provinces are essentially dispersive barriers, either physical, climatic or ecological, which confine species geographically. It is likely that within such areas, similar landscape scale ecological processes are occurring. The recognition of such boundaries is critical to the conservation of biodiversity particularly if boundaries define areas with many endemic, rare or threatened biota. There is, therefore, a critical relationship between biogeography and conservation (Craw et al., 1999). In essence, the biodiversity question is really a biogeographic one.

Conservation planning is often faced with the question of where land should be set aside for conservation, how much there should be, where limited financial resources should be applied and how such land should be managed. Unfortunately, historical biogeographical analyses are not playing the role in biodiversity conservation that they should (Crisci, 2001). Where the geographical distributions of many organisms overlaps or coincides, there exist what are known as biodiversity "hotspots" (e.g. Myers et al., 2000) or high concentrations of rare species (Prendergast et al., 1993). An understanding of full geographical ranges of individual taxa or groups of taxa is also useful in determining zones of ecological transition (Araújo, 2002). The spatial patchiness in the distributions of organisms is also helpful in determining the degree to which species turnover rapidly in the landscape (beta diversity). This is of fundamental importance to conservation because it recognises the ecological scale at which land should be reserved or managed for biodiversity and is essentially a biogeographical issue. Identifying areas with high levels of species richness, coupled with an understanding of beta diversity allow the opportunity to meet the goals of representativeness and complementarity sought in protected-area systems (Spector, 2002). The distribution of species may also transgress geopolitical units within which administrative decisions are made (Rodrigues & Gaston, 2002). In this instance too, biogeographical analyses are extremely important.

Early attempts at delineating Australian zoogeographical areas lacked a clear methodological framework (Moore, 1961). The basis for recognising a zoogeographical region should be clear but was often not. While not questioning the validity of the regions as recognized at the time, Moore (1961) set out four criteria that could be used to test the validity of a zoogeographical region. These were succinctly summarised by Jenkins (1982) and are repeated here:

- A zoogeographical region must have boundaries that can be determined with a moderate degree of precision;
- A zoogeographical region should have fauna markedly different from the fauna of the adjacent zoogeographical region;
- A significant proportion of the fauna of the zoogeographical region should have (geographical) ranges approximately co-extensive with the region, and

- A zoogeographical region should be an area isolated in the present time or during its past for a sufficient period of time to have allowed the fauna to differentiate.

1.3. ECOLOGICAL BIOGEOGRAPHY

Ecological biogeography is valuable because it allows for the identification of ecological characteristics or processes responsible for maintaining the geographical or temporal distribution of species. This facilitates an ecological basis for the development of appropriate management strategies to ensure that, in areas managed for conservation, these processes continue or threatening processes can be abated. Ecological biogeography studies are extremely valuable in identifying true short-range endemics confined by the narrowest of boundaries and which have the greatest likelihood of extinction (Gaston, 1994). The boundaries of geographical ranges of species are dynamic, influenced by environmental conditions and subject to change when environmental conditions change (Brown, Stevens & Kaufman, 1996). How species interact with environmental changes leading to range contraction, expansion and sometimes extinction is of fundamental importance to conservation biology (Channell & Lomolino, 2000). The true nature of these boundaries is made much clearer by elucidating the patterns of the past. Both historical and ecological biogeographical analyses contribute to our capacity to predict what might happen in the future when environmental conditions of ecological processes change. For either ecological or historical biogeographical analyses to be successful, they must be based upon a detailed knowledge of the locality (Craw et al., 1999).

Olson et al. (2002) identified four critical areas necessary for conservation biology research to help stem the impending loss of biodiversity. These were: (1) conserving those species and ecological processes that require the greatest area to persist (minimum-area requirements); (2) conserving widespread species and continental-scale phenomena; (3) quantifying patterns of beta diversity and endemism; and, (4) predicting the location and intensity of threats to biodiversity. The third research priority is a simply a question of biogeography and taxonomy, while the others have significant biogeographic components. Biogeography studies both historical and ecological are therefore critical to the successful biodiversity conservation efforts.

1.4 BIOGEOGRAPHICAL ISSUES IN THE SOUTH WESTERN AUSTRALIA

The south west of Western Australia is recognised as one of twenty-five global biodiversity hotspots where exceptional concentrations of endemic species are undergoing habitat loss (Myers et al., 2000). An ancient geology and a long history of isolation have created unique and complex landscapes. It is a seasonally dry region of steep rainfall gradients and subdued topography; an ancient landscape in which the

existence of relictual taxa depends on refugial moist microhabitats provided by fine-scale hydrological patterns persistent at a local scale (Wardell-Johnson & Horwitz, 1996). Recent human impacts upon this environment have been pervasive, and, in landscapes that contain many Gondwanan elements in habitats reminiscent of those of ancestral rainforests, successful conservation of the region's biota requires on-going and systematic research (Hopper et al., 1996).

Such extraordinary biodiversity requires sensitive management and at a scale that is sensitive to patterns of endemism and beta diversity. Consequently, the scale at which management prescriptions are applied has been the subject of much scientific debate (Wardell-Johnson & Horwitz, 1996; 2000; Abbott & Burrows, 1999). Wardell-Johnson and Horwitz (1996) highlighted the need for finer scale resolution of biodiversity gradients and the recognition of endemism and relictual habitats. Abbott and Burrows (1998) argued that the diversified nature of both silvicultural and logging techniques added to the heterogeneity of the landscape, and that, maintaining forested landscapes in a series of post-disturbance successional stages serves to facilitate recolonisation of species displaced by logging or burning. As will be shown below, the current biogeographical understanding of south-western Australia has been derived almost entirely from the distribution of vegetation associations. Since conservation and management are based upon boundaries drawn from the distributions of few conspicuous and dominant tree species, there are a number of important and pressing hypotheses that need answering. How well do current biogeographical boundaries of the region act as surrogates for elements of the fauna that are not as well understood? What are the fundamental physical, climatic and ecological barriers for these faunal groups? Are there significant areas of richness, endemism or areas of conservation concern? What effects do broad-scale management practices have upon short-range biota? The overall aim of this thesis is therefore to develop an ecological and historical biogeography for a group of organisms whose distribution is likely to reflect a range of regional biophysical elements that have been shown to characterise the region, with the purpose of contributing to the effective management and conservation of regional biodiversity. The group of organisms used was terrestrial isopods (Crustacea: Isopoda) and the reasons for their selection will become apparent during the course of this chapter.

1.5. UNDERSTANDING THE LOCALITY

Craw et al. (1999) suggested that an understanding of locality is vital to any biogeographical analysis. Therefore, an appropriate place to start is to examine what has so far contributed to our biogeographical understanding of southwestern Australia. Western Australia itself contains the oldest known fragments of the Earth's crust (Hopper et. al. 1996) and its geological backbone, the Yilgarn Block, is of Precambrian origin (Mulcahy, 1967). Some surface expressions of this ancient bedrock date back some 2,500 million years (De Laeter & Libby, 1993). Its biogeographical regions have

frequently been the subject of debate and their exact demarcation and the number of divisions made has often differed according to the groups studied (Jenkins, 1982).

1.5.1. THE SOUTH WEST BOTANICAL PROVINCE

The earliest biogeographical boundaries within Australia recognised the uniqueness of south-western Australia. Tate (1887) identified three regions: the Euronotian (lit. south-east wind), the Autochthonian (lit. of the original race) and the Eremian (lit. desert). The Euronotian covered most of the south and eastern parts of Australia while Western Australia was characterised by the Autochthonian, the southwest corner coinciding approximately with the 20 inch (~500 mm) rainfall isohyet, and its remaining parts, namely the Eremian, which was centred in the Lake Eyre Basin. Western Australia contains some ancient and clear cut geological boundaries (Mulcahy, 1967). Biogeographical boundaries, however, have resulted from a long-standing tradition of phytogeographic mapping (Beard, 1980a) and it is strikingly evident that from the earliest times, Western Australia has been characterised by two things, vegetation and rainfall. One of the earliest attempts at mapping the Australian vegetation was by Diels (1906) (Figure 1.1). He identified a floristic boundary, coinciding largely with Tate's Autochthonian region, which he called the South-west Botanical Province[1] and a region that is now recognised as by far the most significant centre of plant endemism in Australia (Crisp et al., 2001).

Diels (1906) recognised four vegetation types: (1) Littoral formations; (2) Woodland formations; including eucalypt forests; (3) Shrubland formations; and, (4) Swamp formations and divided the South-west Botanical Province into six botanical districts which he named Irwin, Avon, Stirling, Darling, Warren and Eyre (Figure 1.1, inset). Diels identified several woodland types characterised by their dominant tree species: Eucalyptus forests, being either Eucalyptus marginata Donn Ex Sm (jarrah), E. diversicolor F. Muell. (karri) or E. wandoo Blakely; transitional woodlands fringing Eremaea, and mixed woodlands in western coastal areas. Diels' vegetation map proved to be intuitively accurate. He defined sclerophyll forest/woodland by an upper storey dominated by eucalypts with many small shrubs in the lower storey and no grasses in the ground layer. Sklerophyllen-wald, which encompassed his Warren and Darling Botanical Districts, concords well with the distribution of Corymbia calophylla (Lindley), the most widely distributed forest eucalypt in the southwest, given later by Churchill (1968). Diels' boundaries probably represent the first true biogeographical boundaries for Western Australia. They started a long preoccupation with the importance of rainfall and vegetation structure and are the first conception of a region dominated by eucalypt forests and woodlands with dominant single species characterising the vegetation.

[1] First recognised by F von Mueller in 1883

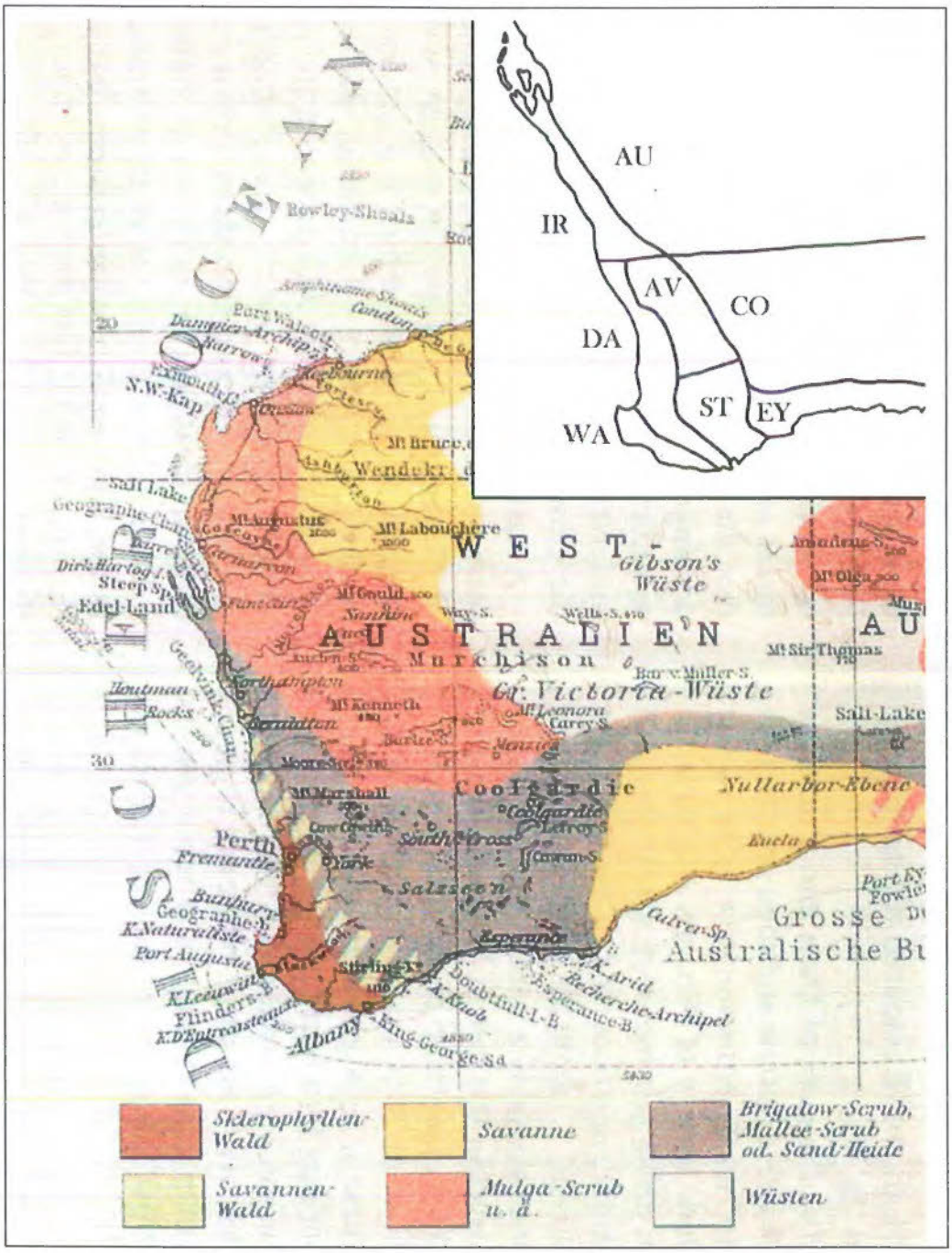

Figure 1.1. A modified section of a vegetation map of Australia by Diels published in 1906 (Source: Beard, 2001). The south-west corner is described as "Sklerophyllen-Wald" (sclerophyll woodland/forest). The sclerophyllous nature was apparently indicative of the understorey and not of the leaf type of the dominant eucalypts. By this means, "sklerophyllan-wald" is distinguished from the grassy-floored savannen-wald (Beard, 2001). Inset is Diels' (1904) phytogeographic scheme (modified from the representation given by Beard (1981a, p.338) in which he recognised the six districts in the South-west Province namely the Irwin (IR), Darling (DA), Warren (WA), Avon (AV), Stirling (ST) and Eyre (EY) Botanical districts.

At the continental scale, delimitations of the southwestern Australia have been made using a number of vertebrate groups. Most of these also reflect the distribution of rainfall and/or vegetation types. The clearest zoogeographic delineations are found in moisture-sensitive or moisture-dependent taxa and concord well with the South-west Botanical Province. This is well illustrated by the zoogeographic region of Main, Lee and Littlejohn (1958) based on frog distribution and Serventy and Whittell's (1951) scheme for birds. Furthermore, Littlejohn (1981 p. 1328) stated that "the clearly distinctive and delimited endemic anuran fauna of the South-western Region ... was the only area of Australia which justified recognition as a faunal area for anurans".

1.5.2. THE SOUTH WEST CORNER

There has been little synthesis between the distributions of plants and animals in south-western Australia. Biogeographical boundaries have continued to be drawn based upon the distributions of dominant vascular plants. Phytogeographical models have been reviewed at least twice by Beard (1979; 1981a) and a range of schemes was examined by Gentilli (1979). While it is not necessary to retrace the methodology and ideology underpinning each of the attempts to create biogeographical boundaries, a rationale for biogeographic analysis should examine the common themes in the schemes and highlight important milestones. Such an approach should establish the potential for any further biogeographic studies to contribute to our understanding of south-western Australia and identify what are likely to be important determinants in the distribution of key biota.

Clarke (1926) proposed a scheme of natural regions classified according to physiography, geology and rainfall which he believed would account for the distribution of plant species. The most notable delineation was the separation of the Swan Coastal Plain from the Darling Range at the Darling Scarp, the uplifted western edge of the Yilgarn Block. This boundary had not been recognised by previous schemes. He named the two adjacent regions "Perth" and "Jarrah". The boundaries of the Warren District which had been delineated earlier by Diels were not recognised by Clarke. He included the Warren District in his larger Jarrah Region. The Avon and Stirling regions of Diels were included in a larger single region called the "Wheat Belt". This is a curious name for a natural region based on physiographic, geological and rainfall elements. It is also probably not coincidental that, at about this time, the commercial importance of jarrah forest was recognised. Up until then, what had been "unimpeded exploitation" (Calver & Dell, 1998, p. 315) of the accessible forest began to be regulated (Calver & Dell, 1998; Heberle, 1997). Clarke's nomenclature clearly reflects cultural and economic factors. In terms of classification, Diels' Darling District would have had historical precedence over "Jarrah" just as the Avon or Stirling would have had over Wheat Belt. Unfortunately, Clarke's clumsy nomenclature still persists today.

Some time later, the scheme of Gardner (1942) further delineated the South-west Botanical Province. The approach was an ecological one but the principal delimiting

boundary was rainfall. The province was delineated by the winter rainfall isohyet of 10 inches (250 mm). Boundaries were drawn within the Province that reflected the jarrah of the south-west and eucalypt woodland and mallee lands both with areas of sandplain and thicket growth on laterite. The scheme further characterised the region by the presence of the dominant structural, and by now commercially dominant, tree species but fortunately Gardner ignored the socio-economically founded nomenclature of Clarke and restored that of Diels.

The dominance of eucalypts was re-emphasised by the Australian phytogeographic regions of Doing (reproduced in Beard 1981a). Two subkingdoms, Central Australia (Eremaean) and a peripheral Eucalyptus subkingdom were established. The South-west Botanical Province, which was part of the Eucalyptus subkingdom, was represented by two subdivisions: the "Southwestern Forest Region, Heath province"; and the "South-western Forest Province". Apart from some minor differences in its eastern boundary, the distribution of the South-western Forest Province is virtually identical to Diels' delineation of Sclerophyllen-Wald.

Beard (1979) provided the most comprehensive phytogeographic scheme of the region (Figure 1.2). It was determined by reduction from relatively large-scale vegetation association mapping of Western Australia. The forested part of south-western Australia identified by Diels is represented by the Darling Botanical District. The Darling Botanical District defines south-western Australia for the purposes of this study and therefore becomes the point of focus for this thesis from now on. The Darling Botanical District of the study area is also referred to as "the Region".

The long-standing delimitation of the South West Province was upheld by Beard but parts of its boundary are moved further east (compare Figure 1.1, inset and Figure 1.2). Diels' original Darling District was extended by Beard to include the Warren District and parts of the Avon and Stirling Districts. Beard delimited the eastern boundary of the Darling Botanical District where the marri-wandoo woodlands give way to the more easterly woodlands of E. loxophleba (York gum) and E. salmonophloia (salmon gum), again emphasising biogeographical boundaries created by the distribution of dominant eucalypt species. The Darling Botanical District itself was divided in four subregions. The Drummond Subdistrict reflects the stark geological divide between the Darling Scarp and the Swan Coastal Plain previously delineated by Clarke (1926). The Warren Subdistrict represents a contracted version of Diels' original District, while the remaining parts of Clarke's Jarrah Region are represented by two subdistricts, Dale and Menzies, defined by slightly different forest understories. The subdistricts themselves are composed of a number of vegetation systems and are shown in detail in Figure 1.3.

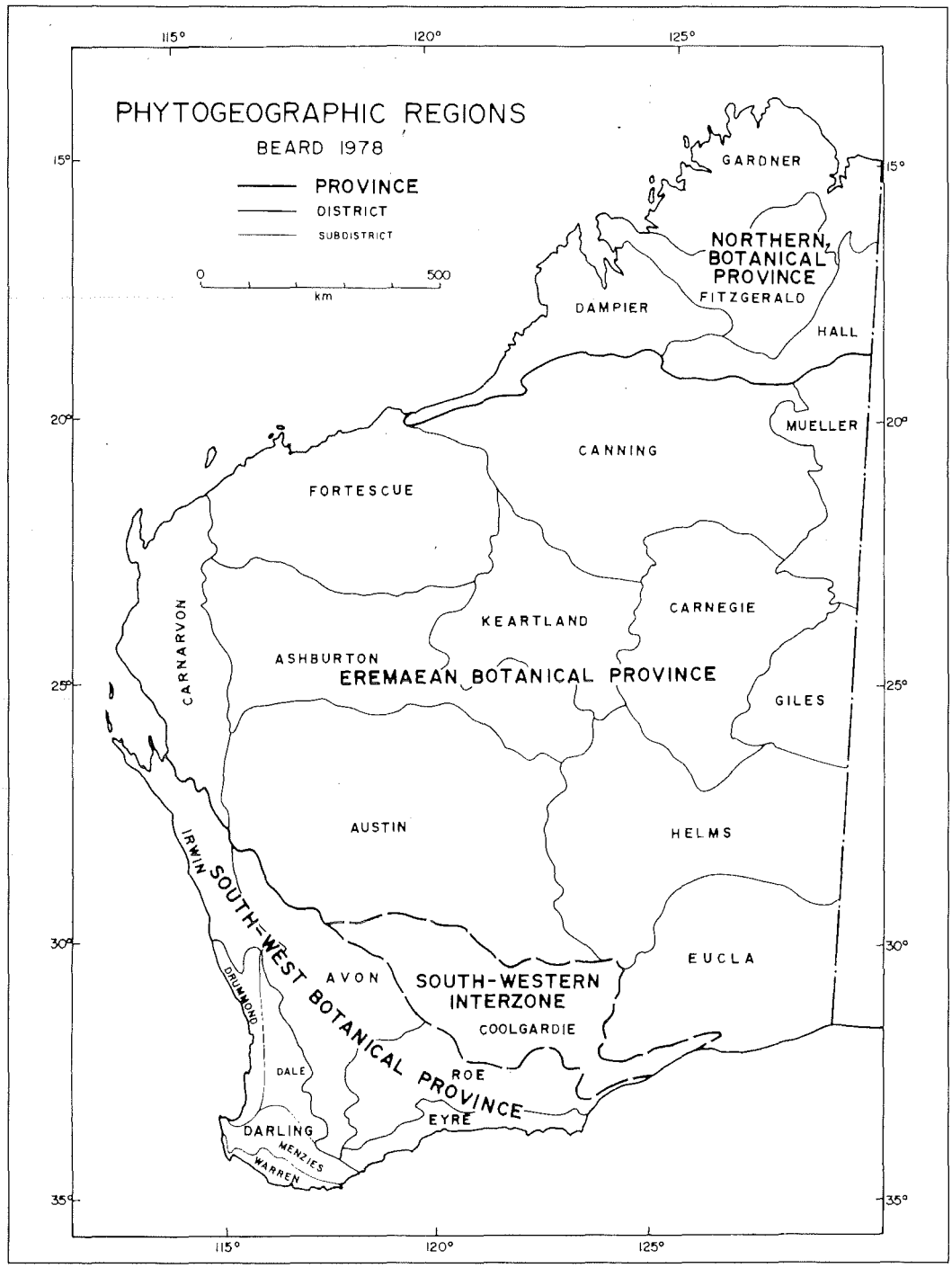

Figure 1.2. The South-West and other phytogeographic provinces, districts and subdistricts of Western Australia (Source: Beard 1979, p.106). The study focuses on the Darling Botanical District which is illustrated in greater detail Figure 1.3.

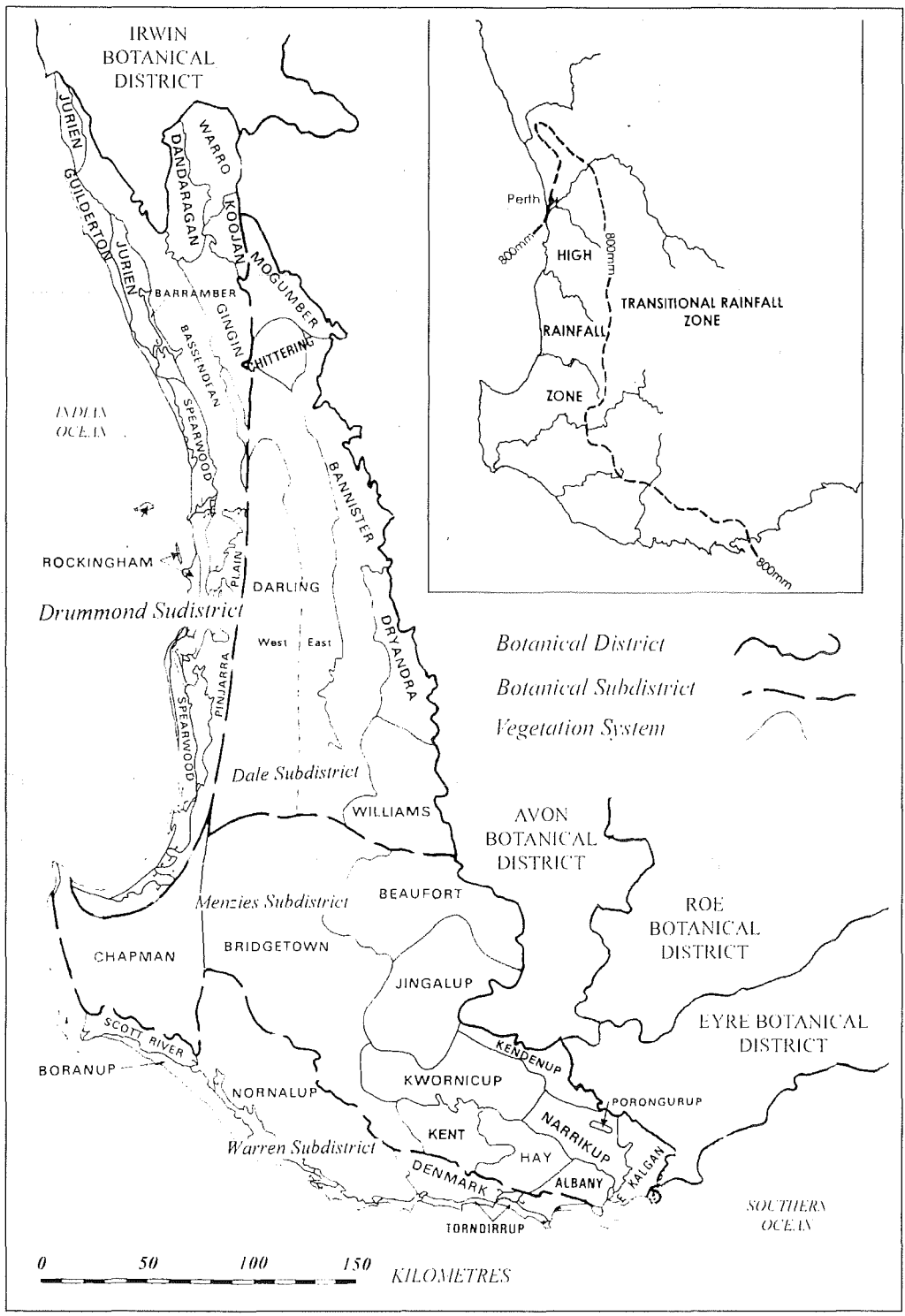

Figure 1.3 Two biogeographical schemes for south-western Australia. The Darling Botanical District of Beard (1981b) showing the subdistricts and vegetation systems and, inset, the High Rainfall and Transitional Rainfall Zones of Hopper (1992).

1.5.3. THE HIGH RAINFALL ZONE

At around the same time as Beard's phytogeographic mapping, Hopper (1979) presented a climatic model in which he identified a High Rainfall Zone (HRZ) and a Transitional Rainfall Zone[2] (TRZ) (Figure 1.3, inset). Whilst biogeographical boundaries were based upon rainfall, the model was used to explain contrasting patterns of plant diversity Boundaries coincided with the 800 mm isohyet and the resulting HRZ and TRZ have been used frequently by other workers in explaining other biogeographical patterns. The inland TRZ is highly speciose in a number of genera of woody perennials in families such as Myrtaceae, Proteaceae, Fabaceae and Epacridaceae (Hopper, 1979; 1992) and the HRZ is notable for its high diversity of eucalypts (Wardell-Johnson & Williams, 1996). The HRZ includes the entire Warren Botanical Subdistrict, which is particularly species rich in wetland monocotyledon genera Cyperaceae, Xyridaceae, Juncaginaceae, Restionaceae and Orchidaceae (Hopper, 1992; Wardell-Johnson & Williams, 1996).

1.5.4. INTERIM BIOGEOGRAPHIC REGIONALISATION.

The Interim Biogeographic Regionalisation for Australia (IBRA, Thackway & Cresswell, 1995) is the most recent and comprehensive attempt at drawing biogeographical boundaries. Its purpose was to establish a framework for a national system of protected areas as a foundation for the conservation of continental biodiversity (Thackway & Cresswell, 1995). The methodology used for developing the IBRA for Western Australia was based largely upon the floristic mapping of Beard shown in Figure 1.2 with consideration also to climate, geology, and vertebrates. The IBRA regions (Figure 1.4) represent "an interpretation of all previous regionalisations tempered with field-based knowledge" (Thackway & Cresswell, 1995, p.26). With the exception of the Stirling District, which Beard abolished, the names given by Diels in 1906 rightly persist today. Regarding nomenclature, the IBRA stated that:

"Where possible region names and descriptions for the IBRA utilised existing common names and referenced source documents. Where no appropriate names and descriptions were available, field knowledge was used to generate these" (Thackway & Cresswell, 1995, p.5).

Beard (1980) was the source document for the IBRA (Thackway & Cresswell, p.26) and, in this light, some points are worthy of note. With the exception of the Darling Botanical District, the focus of this study, each of Beard's botanical districts are represented by a single IBRA bioregion. The Darling Botanical District is however represented by three, the Swan Coastal Plain, Jarrah Forest and Warren Bioregions.

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[2] The TRZ is generally referred to as the Intermediate Rainfall Zone at the present time

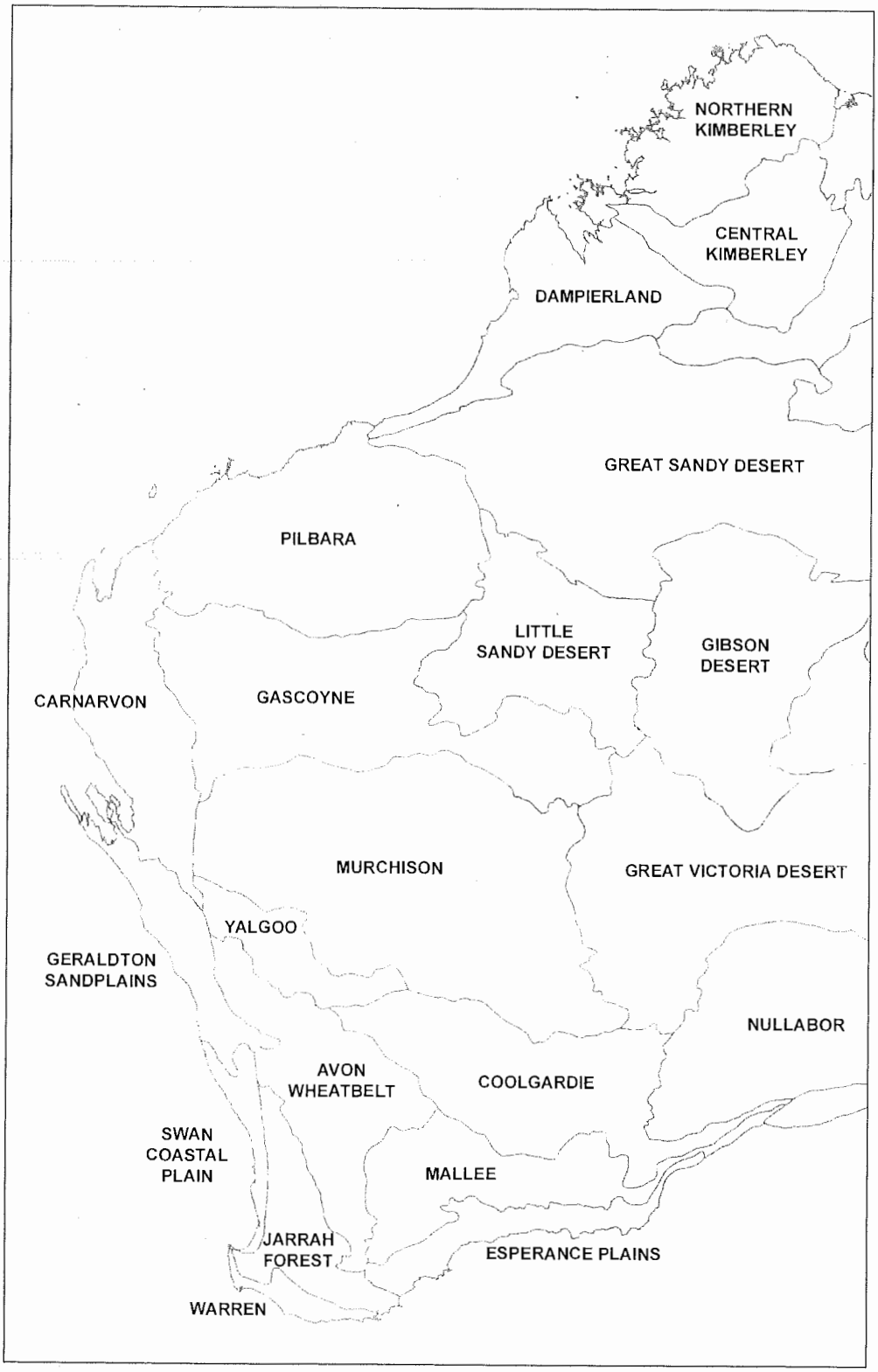


Figure 1.4. Bioregions of Western Australia as determined by Thackway and Creswell (1995) (Modified from Thackway & Cresswell, 1995). Note the similarity to Beard's phytogeographic regions in Figure 1.2.

The IBRA recognises both the Drummond and Warren Subdistricts as bioregions whereas the Dale and Menzies were combined to form the Jarrah Forest Bioregion. This suggests that the division between the Dale and Menzies subdistricts[3] was less marked than that of the Dale and Drummond subdistricts or the Menzies and Warren Subdistricts. This is an assumption that needs to be tested in the course of this biogeographical analysis.

This Jarrah Forest Bioregion should have been called "Darling Bioregion". This is because firstly, there is some concordance with Diels' (1906) district of the name and secondly, the IBRA bioregion is a contraction of Beard's (1981b) district. The name "Darling" clearly had historical precedence and was a fundamental part of the source document. If the Jarrah forest was not considered concordant with either of the previous delimitations, then it should have been called the Dale-Menzies Bioregion since it was an amalgam of both subdistricts. The same could be argued for the Swan Coastal Plain Bioregion, since it is entirely concordant with Beard's Drummond Subdistrict. However, the term Swan Coastal Plain is recognised as a natural unit from many points of view (Seddon, 1972). Clarke's use of the cultural term "wheatbelt" was perpetuated by IBRA, despite the fact that Diels' original district name of Avon was added to it.

The key point here is that early perceptions showed south-western Australia as a homogenous forest system, or systems, characterised by its dominant eucalypts. This has continually been continually been reinforced. Although Beard's phytogeographic mapping placed emphasis upon the grouping of a complex of vegetation systems, some of which were derived from the distributions of some characteristic eucalypt species, the scheme itself did not imply either the dominance of certain species or the homogenous nature of the region. The IBRA, although it was based upon Beard's work, through selective delineation and unfortunate nomenclature reinforced the perception of a homogenous forest system.

1.5.6. MANAGEMENT BOUNDARIES

Increasingly, and perhaps starting with the scheme of Clarke (1926), the forest ecosystems of the Darling Botanical District have been characterised by the distributions of merchantable tree species (Wardell-Johnson & Horwitz, 1996). This had led to conception of the forest as a few very distinct and homogenous forest types. The perception of homogenous ecosystems dominated by single merchantable eucalypt species has underpinned much of the management strategies of various Western Australian stage agencies charged with overseeing timber production and/or nature conservation. Homogenous forest types are clearly illustrated by Figure 1.5.

[3] Recognised later as a subregional division (NLWRA, 2002)

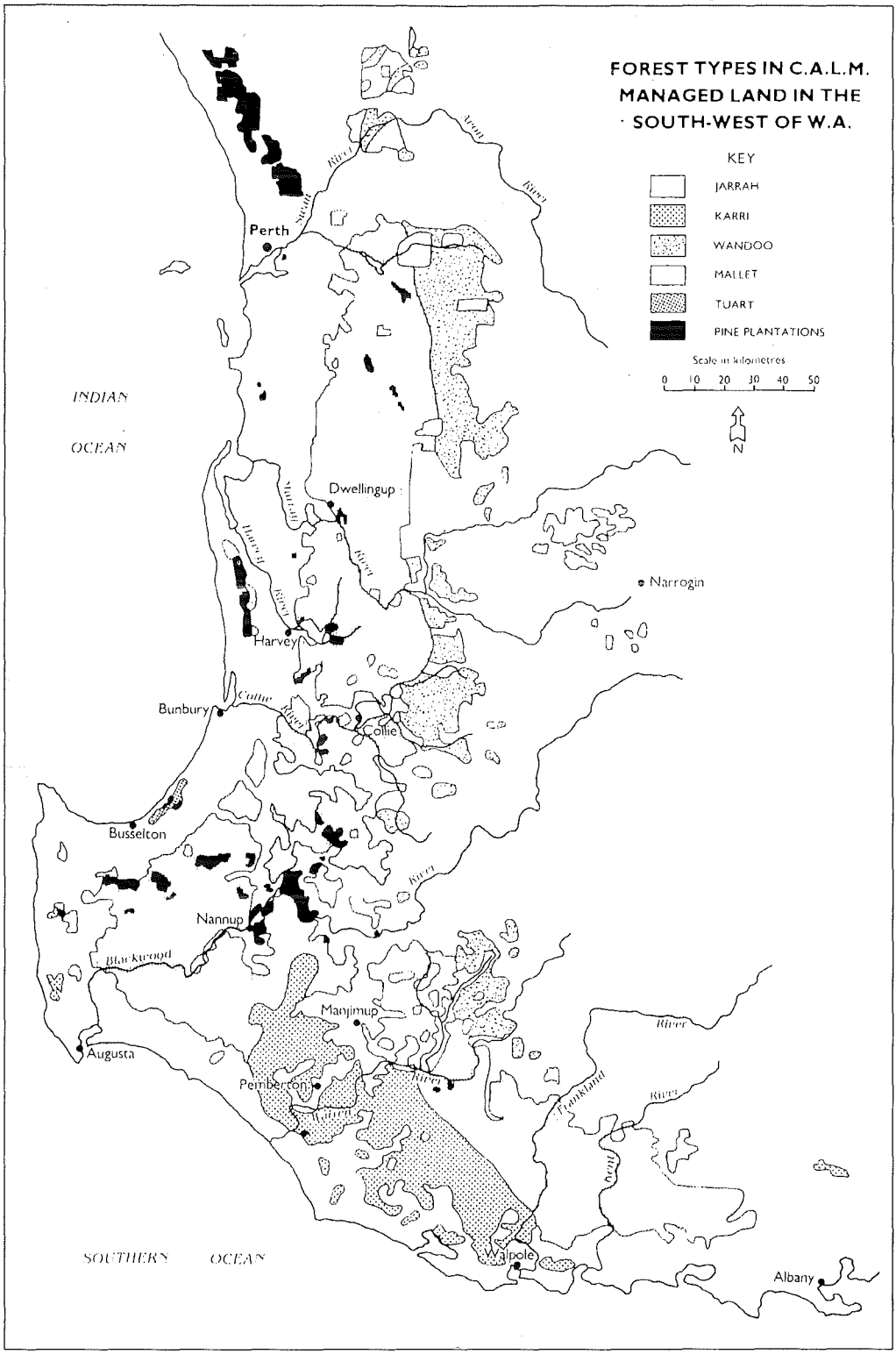


Figure 1.5. The extant distribution of the main forest types in South-western Australia. Forest types are and have historically been characterised by the dominant eucalypt species. Major rivers of the region are also shown (Source CALM, 1992)

Within the Darling Botanical District, much of the land not already modified by urbanisation or agriculture occurs as part of the forest estate and, consequently, the conservation of much of South-western Australia's biodiversity is dependent upon the reservation and sympathetic management of these areas. More recent mapping (Mattiske & Havel, 1998) as part of the Commonwealth and State Regional Forest Agreement process (Commonwealth of Australia & State of Western Australia, 1998) recognised much more complex forest vegetation communities. This mapping facilitated a significant expansion of the conservation estate but has not resulted in changed management boundaries or significantly altered silvicultural techniques or burning regimes (Conservation Commission, 2003).

Conservation managers and policy makers must integrate an overwhelming number of biological and socioeconomic factors to prioritize conservation efforts (Pearson & Carroll, 1996). Therefore, complex mapping of all biotic elements and the consequental development of appropriate administrative boundaries is fundamental to effective conservation and management. This is particularly so in heterogenous landscapes recognised globally for their biodiversity. Boundaries that reflect accurately the distributions of important species, and encompass districts within which similar ecological processes are operating, are critical. When such boundaries are defined, conservation estate planners have the opportunity to meet the goals of representativeness and complementarity in protected area systems (Spector, 2002) and land managers can develop strategies specific to the conservation needs of the district in question. Biogeographically-based administrative boundaries also allow for the optimal allocation of limited conservation funds, concentrating on those parts of the landscape most at risk or in need of intensive management and leaving alone those which need little intervention.

Ecological boundaries also allow for a geographical or ecosystem approach to management rather than a species by species approach. When the geographical boundaries of taxa coincide with the delineation of ecological regions, their distributions can be used to predict spatial patterns of biodiversity (Pearson & Carroll, 1998). Such taxa may be considered as biogeographical "indicators". In south-western Australia a case could be argued for using dominant eucalypts as indicators. However, as Pearson and Carroll (1998) stated, the biogeographical and ecological history of such species must be taken into account. Other than some small-scale and valuable studies (e.g. Wardell-Johnson & Coates, 1996) this is yet to happen for south-western Australian eucalypts.

Management of public lands, including the conservation estate, is currently carried out by the Western Australian Department of Conservation and Land Management (CALM). The legislative framework in which it operates has been set out various times (CALM. 1987a; 1987b; 1987c; CALM 1992, Conservation Commission, 2002). The principal instrument is the Western Australian Conservation and Land Management Act, 1984 (CALM Act) and one of the major functions of CALM is to "conserve the indigenous biota

and ecological processes in natural habitats" (CALM, 1995). Management by CALM is facilitated by a series of management regions. These are not natural regions and reflect not biogeographical boundaries but a range of current and historical administrative boundaries. The management regions encompass between three and five districts, which are essentially old Forest Department districts with administrative centres originally part of the timber industry infrastructure.

The conservation estate of national parks, nature reserves and other land referred to in section 5(1)(g) and (h) of the CALM Act that has a conservation purpose, is required to be managed according to the Conservation and Land Management Act, 1984 and the Western Australian Wildlife Conservation Act (Conservation Commission, 2002). This is undertaken through the preparation, public revue and ministerial approval of management plans. Management plans are prepared for specific parks or reserves and forest management plans are prepared to ensure that ecologically sustainable management occurs in multiple use forest. The principle underlying multiple use is that, while the provision of a representative reserve system where the priority value is nature conservation is an essential component of the total management strategy, areas outside of the conservation reserve system will be managed so that forest ecological processes (including its biological diversity) are maintained (CALM, 1992).

1.5.7. THE MANAGEMENT ISSUE

CALM manages south-western Australian ecosystems for both commercial exploitation and nature conservation. Management techniques have been the subject of much polarised debate among the scientific community. As well as the issue of scale highlighted earlier, much of the debate has focussed on the application of ecological principles to management, particularly silvicultural practices and the application of broad-scale fire regimes (Abbott & Christensen, 1994; 1996; Calver et al., 1996; 1998; Calver & Dell, 1998a; 1998b).

Broadly speaking, two types of fire regime and silvicultural practices have been developed, one for jarrah and one for karri (distribution in Figure 1.5). The purpose of prescription burning is to periodically reduce fuel to manageable levels in order to safeguard human life and infrastructure, timber values and to promote the commercial regeneration of the forest. Prescription burning, in which management units (forest blocks) are intentionally and rotationally burned (Wardell-Johnson & Nichols, 1991), is designed to systematically remove organic matter from the landscape. Jarrah forests are burned periodically on about five- to eight-year rotation to keep fine fuel loadings below eight tonnes per hectare while karri forests are burned on about a nine-year rotation (Christensen & Abbott, 1989; McCaw, Neal, & Smith, 1996). About forty percent of the forest estate has been burned within the last six years and current targets are to burn about 200,000 hectares per year (R. J. Sneeuwjagt pers. comm. 7/11/2003).

Silvicultural practices for jarrah are relatively complex. From the mid-1980s, a combination of systems has been used, depending on the structure of the forest and the condition of the existing lignotuber regeneration. These include gap logging, to release existing lignotubers so they can develop into saplings, and thinning of immature stands that are still actively growing to promote growth on retained stems. Where few lignotubers are present, regeneration is from seed. Shelterwood cutting and follow up burning are used to promote the conditions for germination, regrowth and subsequent development of a lignotuber pool. In low quality stands, single tree selection is carried out. Over the past three years the average annual area cut over was 18,000 hectares (Conservation Commission, 2002).

Silvicultural practices for karri differ from those of jarrah. Because of its large size at maturity and because it only regenerates from seed, karri forest coupes are clearfelled. Felled coupes are subsequently burned to promote karri regeneration from seed. The minimum size patch for effective management is approximately two hectares, while the maximum is constrained to forty hectares for visual and biodiversity reasons (Conservation Commission, 2002).

1.6. THE NEED FOR AN ALTERNATIVE VIEW

The past century and a half have seen some fundamental changes in the way that south-western Australian ecosystems are utilised and resulted in some significant changes in the mammal fauna. Therefore, assessing the zoogeography of mammals of the region is complicated by the fact that distributions of many taxa are remnants of former continental-wide distributions. In this sense, the mammal distributions are indicative of European-induced exogenous disturbance at a continental scale. However, there is therefore clear evidence, at the broad scale that the moist and forested nature of the south west corner of the continent is clearly of fundamental importance to continental zoogeography. Invertebrates communities however, present spatial patterns far more complex than vertebrates and arguably dominate the functions and processes of most ecosystems (Horwitz, Recher & Majer, 1999). The conservation of biodiversity, in what is recognised as a global hotspot, must address the dual and inter-related issues of ecosystem functioning and the role of invertebrates (Horwitz et al., 1999).

Invertebrates, despite being less exhaustively documented than vertebrates or plants, still show some interesting patterns. There is evidence that the biogeographical boundaries their distributions create are significantly different to those illustrated above. Terrestrial and aquatic invertebrates have been well studied in south-western Australia and occasionally provide some clear fine–scale zoogeographic patterns. Many studies involve the documentation of invertebrate communities across a range of sites which are then explained by a suite of environmental parameters. These are essentially small-scale ecological biogeography studies. Some studies have been primarily ecological in nature (e.g. Bayly, 1982; 1992; Abbott, 1985) whilst many have been driven by strategic

management aims (e.g. Bunn, 1983; Bunn, Edward & Loneragan, 1986; Bunn & Davies, 1992; Storey et al, 1990; Balla & Davies, 1993; Horwitz, 1994), or the desire to detect impact of management practices such as logging (Curry, et al., 1985; Growns & Davis, 1991; 1994; Abbott, et al., 2003), and fire (e.g. Springett, 1979; Abbott, 1984; Majer, 1984). Literature concerning terrestrial invertebrates in Western Australia was collated by Majer and Chia (1980) and the impacts of disturbance in forested areas were reviewed by Majer and Heterick (1997). While some useful biogeographical information can be gained from such studies, the time spent obtaining extracting, compiling, synthesising analysing the data and sorting out deficiencies in taxonomy, makes this process sometimes less favourable than undertaking an original study. The fact that many of the terrestrial invertebrates of the south-west of Western Australia are yet to be named (Majer & Abbott, 1989; Main 1996a) means that much of taxonomic information is normally useable only at the ordinal level.

Main (1996a) identified two components necessary for the certain conservation of terrestrial invertebrate biodiversity in the forested south-western Australian. These were: (1) an understanding of the distribution and habitat of terrestrial invertebrates; and (2) that this understanding be based upon a meaningful geographical template. The perception of forests as homogenous units is hardly an adequate starting point. This, she stated, needs to be carried out "taxon by taxon" by various specialists in a coordinated manner (p.280). The first part of this thesis aims to do just that. There is thus, a clear and overwhelming need to undertake an invertebrate biogeography of the south-west of Western Australia. Given the comments above, this must involve a large amount of taxonomic work. The principal aim of this study is to document "taxon by taxon" the terrestrial isopods of south-western Australia and to provide a biogeographical framework by which their distributions can be evaluated.

Much valuable fine scale distributional invertebrate data can already be found in a number of taxonomic works. However, this information is rarely synthesised, so readily and rapidly accessible lists of taxa are rarely collated at any meaningful scale (Main, 1996a). Furthermore, much of the taxonomic literature does not contain habitat or microhabitat data essential to determining the likely ecological biogeography of many invertebrate species. This is further exacerbated by the fact that the collection and description of invertebrates are increasingly becoming separate processes. Specimens might be collected by a specialist ecologist and described much later by a taxonomist both geographically removed from the point of collection and without the first hand knowledge of how, why, and precisely where, the specimen was collected.

An example of a synthesis of taxonomic and other literature was undertaken by Abbott (1995) for insects of forested areas. The taxonomic list provided represents an important resource for ecologists, taxonomist and biogeographers alike. However, the boundaries of the study region delineated by Abbott are problematic in a biogeographical sense. Insects were documented only if they occurred in the forested part of south-western

Australia, or, as defined by Abbott (1995 p.365), either the jarrah or karri forests. On the eastern boundary of the Darling Botanical District, vegetation mapped as jarrah-marri-wandoo woodland was included in the area of study while wandoo woodland or wandoo-marri woodland was excluded. The Swan Coastal Plain was also excluded, despite the fact that it has significant forest and woodland associations (or had when many of the insects listed were collected) and "many records found from Waroona and Yallingup, although close to the forest" were excluded. Interestingly, jarrah forest itself was considered to form northern and southern zones. Despite the obvious limitations in developing a regional understanding from such a study area, one major biogeographical finding is of note. Twenty four percent (23.6 %) of all species so far recorded occurred in both the southern and northern forest zones, 30.4% occurred only in the northern forest zone and 46.1% occurred only in the southern forest. Of those found only in the southern forest, 49.7% were found only in the karri forest. This indicates not only a distinction between the "jarrah" or "karri" forests but also an even greater distinction between the northern and southern parts of the jarrah forest. The boundary of the northern and southern jarrah forest, given as the Preston River, appears to reflect an administrative boundary. However, it is similar to Beard's delimitation of the Dale and Menzies subdistricts. Since the boundary was determined a priori and not delineated from distributions found in the study, and because the wider distribution of the taxa was not investigated, it is not a true biogeographical boundary. Nevertheless, as was the intention, it does provide in a limited form, a reference point for future biogeographic studies and created a potential biogeographical boundary not previously recognised.

There have been some other significant and fine scale studies on the distribution of invertebrates. Rossbach and Majer (1983) studied ants in the Perth region and showed distributional patterns associated with various vegetation types of the Swan Coastal Plain and Darling Range. However, Bunn (1983) examined termite distribution over a similar area and found no distinction between the fauna of the Swan Coastal Plain and Darling Range. Harvey (2002) gave some extraordinary statistics regarding both the diversity and ranges of species in the paradoxosomatid millipede genus Stygiochyropus. He estimated that upward of ninety species are found in south-western Australian and South Australia. Distributions range from over 28000 km^2 to 5000 km^2 and many are known only from single sites. The mechanisms of speciation are not yet fully understood, but Harvey (2002) suggested widespread allopatric speciation may be the result of variation in soil and vegetation type across the landscape.

1.6.1. THE IMPORTANCE OF MOISTURE

While floristic boundaries have been related to annual or seasonal rainfall at the broad scale, the importance of rainfall, its seasonality and the persistence of moisture regimes within the landscape are shown in the patterns of some aquatic invertebrates of the region. These have been relatively well-studied and illustrate some of the finer scale patterns within the Darling Botanical District. Unlike patterns of richness for vascular

plants that were shown by Hopper (1979; 1992) to be richer in the TRZ, the richness and diversity of aquatic invertebrates is understandably greatest in the HRZ.

Amongst these are the freshwater crayfishes in the family Parastacidae. All non-introduced species of Parastacidae are endemic to the Darling Botanical District and demonstrate endemism at a range of scales. Cherax quinquecannatus is confined to the Darling Botanical District and is widely distributed within it (Judd & Horwitz, unpublished data). Morrissy (1978) showed the probable extent of the original distribution of marron (Cherax cainii) in the rivers of South-western Australia. While it is restricted to the southern part of the Darling Botanical District, the species is one of the most widely distributed of the freshwater crayfish. It occurs in the river systems of much of the forested area as far north as the Harvey River (see Figure 1.5) and as far west as the Kent River (see Figure 1.5). The distribution of another species, C. crassimanus, is almost entirely concordant with the Warren Botanical Subdistrict and C. glaber is found almost entirely between Augusta and Busselton (see Figure 1.5) (Judd & Horwitz, unpublished data). Within the Warren Botanical subdistrict itself there are some significant small-scale biogeographical patterns. Five species of Engaewa, a genus endemic to the Warren Botanical subdistrict, occupy well-defined and largely non-overlapping geographical ranges (Horwitz & Adams, 2000). Trayler et al. (1996) suggested that 17% of the aquatic invertebrate taxa found within Warren Botanical subdistrict are locally restricted. Patterns of short range endemism in the Warren Botanical Subdistrict have also been demonstrated by Horwitz (1997) and Bayly (1992).

The distinctiveness of the Warren Botanical Subdistrict as a biogeographical unit is well supported by its aquatic fauna (Trayler et al, 1996; Judd, Horwitz & Jones, 1999). It is a region of many short range endemics whose persistence is dependent upon fine scale hydrological patterns (Wardell-Johnson & Horwitz, 1996). The presence of many short-range endemics is an important one. Harvey (2002) defines conservatively short-range endemics as being confined to less than 10,000 km^2 The challenge of conserving a landscape rich in short-range endemics requires reservation and management sensitive to the distributional organisms found there. A taxon's range is defined by a series of intrinsic, extrinsic and historical factors (Ponder & Colgan, 2002). Intrinsic factors include dispersal capacities, habitat preferences, life history and physiological attributes. Logically taxa with poor dispersal capabilities and a narrow range of ecological and physiological tolerances tend to have much smaller spatial distributions than vagile taxa capable of withstanding ecological stress (Ponder & Colgan, 2002).

In south-western Australia, environmental stresses often relate to extreme seasonal variability in the availability of moisture. Consequently, many organisms in the Darling Botanical District are found in much smaller geographic ranges now than when the environment was much more uniformly mesic (Harvey, 2002). The aridification of Australia, which commenced during the Miocene (Hopper et al., 1996), led to extinction of some taxa and to a major contraction of the range in many others. The decreasing

availability of moisture over a wide range has led to a landscape dotted with short-range endemic Gondwanan relicts (Hopper et al., 1996; Harvey, 2002), many occurring in cryptic microhabitats. Some taxa found mainly in the Warren Botanical Subdistrict are also found in association with the Darling Scarp and/or with wetland systems of the Swan Coastal Plain mostly near Perth. This pattern is perhaps clearest in the crustacean suborder Phreatoicidea. These ancient isopods are confined largely to freshwater lakes and springs (Wilson & Johnson, 1999) but also occur in permanently moist microhabitats under stones (Wilson & Keable, 2002). The disjunct nature of the distribution of the group was shown by Wilson and Johnson (1999). The genera Paramphisopus and Hyperoedesipus are found in the Perth region while Amphisopus is found in the wettest part of the far south of Western Australia. Similar disjunct distributions are found in the crangonyctoid amphipods (Williams & Barnard 1988), the aquatic amphipod Perthia (Perthidae) and to some extent[4] in the talitnd amphipod Austrotroides (Judd, Horwitz & Jones, 1999). A disjunct pattern has also been recorded for the freshwater galaxiid, Galaxiella nigrostrata, which is found mainly in coastal peat flats from Albany to Augusta with disjunct distributions in small pools in Bunbury and Gingin, approximately 200 and 400 km to the north (Morgan, Gill & Potter, 1996).

These disjunct distributions suggest that there are some clear biogeographical relationships between the Warren Bioregion and northern parts of the Swan Coastal Plain Bioregion that have not been explained by previous biogeographical treatments of south-western Australia. These will be investigated during this study. There is also clear evidence that south-western Australia contains both small-scale invertebrate endemics, areas of high species richness and important disjunct distributions. Further elucidation of such patterns by this study and their concordance with other patterns should produce a much clearer understanding of invertebrate biogeography. This study asks: where are the important centres of endemism, at what scale does endemism occur and how do these relate to the patterns so far identified in south-western Australia? Implicit in this aim is the need to provide a degree of taxonomic resolution fine enough to highlight such patterns.

1.7. TERRESTRIAL ISOPODS

A biogeography of terrestrial isopods has the potential to integrate some of the fine-scale patterns of the various parts of the region with the broader patterns that are evident in the phytogeographic models and which underpin the concept of the HRZ and TRZ. The preceding sections have identified a series of factors important to the distribution of the biota of south-western Australia and highlighted some of the issues that are important to conservation of the region's biodiversity. In other parts of the world the distribution of

[4] I have observed talitrids in wet gullies of HRZ jarrah forest, suggesting some isolated occurrences between the two disjunct populations

terrestrial isopods has been related to various broad-scale climatic and habitat factors and at the fine-scale, soil moisture is probably critical (Warburg, 1993a). Terrestrial isopods are moisture-dependent (Warburg, Linsenmair & Bercovitz, 1984), have a limited dispersal capability and high potential for speciation and extinction. Despite a conservative body plan, they have evolved a range of clear and consistent functional categories (Schmalfuss, 1984). These characteristics suggest that, in south-western Australian landscapes, terrestrial isopods are likely to be diverse, relictual and distributed according to specific biophysical characteristics of the landscape. The following section provides the background and suggests why a study of terrestrial isopods is appropriate.

Terrestrial isopods are adapted to terrestrial life in ways that differ from other arthropods and there can be no doubt as to their success in colonising terrestrial areas of the world (Sutton, 1972). They belong to a single sub-order of the Crustacea, namely the Oniscidea. They have been known as oniscoids[5], oniscids or oniscideans. The history of higher taxonomy of the Oniscidea is convoluted and has recently been elucidated by Schmidt (2002a; 2002b). The classification of Holdich et al. (1984) is probably the most widely used, but has been the subject of some relatively minor (e.g. Schmalfuss, 1989; Wägele, 1989) or complex (Erhard, 1998) modifications. The classification of Holdich et al. (1984) recognised two infra-orders within the Oniscidea, namely the Tylomorpha and Ligiamorpha. The Tylomorpha contained only the Tylidae, while the Ligiamorpha had three sections, the Diplocheta, Synocheta and Crinocheta. These three sections, whether or not they are monophyletic groups, characterise well the terrestrial isopods. The Crinocheta represent by far the overwhelming majority of terrestrial isopods species, and the monophyly of the group is well supported (Schmidt, 2002a). The terms "terrestrial isopods" and "Oniscidea" are synonymous and are used interchangeably throughout this thesis. Terrestrial isopods are also known by a myriad of common names (see Webb & Sillem, 1906) with the most widely-used in Australia being slaters and woodlice. Approximately one hundred and sixty species of Oniscidea have so far been described from Australia, of which about fifty-five are from Western Australia and forty-five are found in the Darling Botanical District.

Terrestrial isopods are an integral part of the decomposition cycle, living off, and in, dead organic matter (Hassall, Turner, & Rands 1987; Zimmer, 2003). At a regional scale, climate affects both the distribution and abundance of terrestrial isopods. Humidity and moisture are paramount in determining their activity and distribution, and the survival of juveniles is particularly dependent upon moisture (Warburg, et al. 1984). Most species are primarily saprophagous, reliant upon litter and other organic inputs in the habitat in which they live. The micro-scale spatial distribution of terrestrial isopod is patchy and is

[5] The term "oniscoids" is incorrect and should no longer be used in the context of the suborder. Kaestner (cited in Holdich et al., 1984) highlighted that the previously familiar suffix -oidea was incorrect and is more correctly applied to a super-family.

governed by differences in available food quality (Rushton & Hassall, 1983; Zimmer & Topp, 1997, 2000; Kautz, Zimmer & Topp, 2000) and microhabitat (Heinzelmann et al., 1995). Isopods, are a conspicuous part of the soil and litter macrofauna and some have body sizes large enough to disrupt the physical structure of the soil during foraging and feeding activities (Anderson, 1988).

The distributional patterns of the Oniscidea suggest that they are likely to respond to a number of environmental variables and present discernible patterns at a range of distributional scales. Their distribution in south Western Australia is therefore likely to reflect both climatic and vegetative characteristics in some way. At the continental scale, Green (1974) recognised four distributional patterns among the genera of terrestrial isopods occurring in Australia:

1) Predominantly supra-littoral world-wide genera;
2) Southern forms, often primitive, most of whose relatives inhabit southern temperate lands;
3) Morphologically more advanced forms whose nearest relatives are mainly in countries north of Australia; and
4) Recently introduced Palaearctic species.

These groupings suggest that the distribution of the terrestrial isopods reflects both evolutionary forces and recent changes to the landscape. The presence of primitive and relictual forms has the potential to highlight areas of particular conservation interest.

An appreciation of the scale at which organisms are distributed is fundamentally important to understanding the nature of the forces determining their distribution (Whittaker, Willis & Field, 2001). Distributional scales have been investigated by a number of workers. Hornung and Warburg (1995) developed a hierarchical series of three scaling levels to show that terrestrial isopod distribution was observable and measurable at a range of spatial scales. Warburg (1993b) reviewed the occurrence of terrestrial isopods within different habitats and showed patterns of zonation have been observed relating to both distance from the coast and to the broad-scale distribution of moisture within the landscape.

The potential for isopods to respond to a range of broad- and fine-scale environmental influences comes from their variety of morphological adaptations despite a conservative body plan (Schmalfuss, 1984) and from a series of behavioural responses. They have a limited ability to conserve water and undertake respiration by means of modified gills (pleopods). More advanced forms respire by a rudimentary tracheal system called pseudotracheae. Neither pleopodal gills nor pseudotracheae have controlled openings. In addition, in only the most advanced forms does the cuticle offer any form of resistance to desiccation. Even in these species, the degree of endocuticular waterproofing is much less than the typical insect. It has been shown recently that isopods within the Crinocheta and Diplocheta have a capacity for active water vapour absorption (Wright &

Machin, 1990; 1995). These behavioural responses in the context of a seasonally-dry climate have a profound influence on their likely geographical distributions.

Terrestrial isopods have not been systematically studied in Western Australia. Indeed, studies of the Australian Oniscidea are extremely sparse. The Oniscidea show varying degrees of adaptation to terrestrial conditions across a range of families and have been able to colonise all Australian terrestrial ecotypes. Some have even developed secondary adaptation to salt lakes (Ellis & Williams, 1970). In addition, terrestrial isopod behaviour is tailored to avoid desiccation. Despite being successful colonists of the land, the Oniscidea are restricted to microhabitats that remain relatively moist. These habitats, such as leaf litter, rotting logs and soil, are often moist due to the presence of organic matter. In a Western Australian context, the build-up and flammability of this same organic matter is of paramount concern for state management authorities. Due to their dependence upon organic matter, the distribution of terrestrial isopods may be, or may become, intractably related to management practices occurring within the region.

The arguments regarding the appropriateness of management techniques have been well argued elsewhere (e.g. Calver et al. 1998) and do not need to be restated here. At the centre of the debate is the issue of scale (Wardell-Johnson & Horwitz, 1996). The degree to which we can effectively manage and conserve regional biodiversity is dependent upon the application of conservation and management strategies sensitive to patterns of endemism. All aspects of forest management activities, and logging and burning in particular, involve the temporal and spatial redistribution or removal of organic matter. Management activities must ensure that organic matter is not manipulated spatially and temporally beyond its capacity to provide suitable habitat for sensitive and endemic taxa. One of the fundamental questions posed by this thesis asks: what are the relationships between terrestrial isopods and organic matter? In particular, what microhabitat types are utilised, how do these vary according to the biogeographical patterns and taxa identified and do their properties influence the species found there? To demonstrate these small-scale ecological barriers, an ecological biogeography will be constructed.

1.8. THESIS OVERVIEW

This thesis examines whether our current biogeographical understanding of south-western Australia is adequate for the successful conservation of the region's biodiversity. It asks whether the current model of three bioregions, constructed from mapping of vegetation associations, is likely to explain the distribution and aspects ecology of a very different group of organisms. How well does a biogeographical model of an invertebrate group wedded to moist microhabitats concord with vegetation associations? By assessing the likely ecological factors underlying the distribution of terrestrial isopods, I ask the all important question; what are the consequences of developing management and conservation strategies based on biogeographical models that are not representative of much of the biodiversity we are trying to conserve.

Specific aims or hypotheses have been developed and stated throughout this chapter. They are summarised and synthesised below. The following section outlines, chapter by chapter, the hypotheses and structure of the thesis and is designed to assist the reader in negotiating a thesis of this scale. The thesis contains eight chapters, each divided into sections, subsections and sub-subsections. Figures, Plates, and Tables are numbered consecutively as they appear within each chapter. While there is a logical progression of ideas and hypotheses, to some extent, each chapter may be approached separately

Chapter 1 provides a biogeographical background and highlights why the study was necessary and important, identifies a suitable organism to study and develops an overriding hypothesis It asks the critical questions, will a biogeography for terrestrial isopods reflect a range of regional biophysical elements that have previously been shown to characterise the region, and, how can such an ecological and historical biogeography contribute to the effective management and conservation of regional biodiversity?

Chapter 2 documents a robust and replicable methodology by which an invertebrate biogeography should be constructed for south-western Australia. The only methodology not given is that for the taxonomy and that which evolved during the course of study set for an individual chapter. Chapter 2 concludes with a glossary of some important terminology and a description of the study area.

Chapter 3 asks how many species are there in the study area and how can they be best identified? The data used to answer these questions come from an extensive review of the literature and by a comprehensive taxonomic examination of all existing collections and newly collected material from south-western Australia The chapter can be read independently and can be approached from various standpoints. At the simplest level, one may examine the plates and marvel at the diversity of the region's terrestrial isopods. At the most detailed, it is possible to reconstruct entirely the taxonomic and biogeographical work from re-examination of the list of material examined. In between these two extremes, it is possible to identify the terrestrial isopods of the region by means of the plates, characters and/or the dichotomous key. The taxonomy of the region s terrestrial isopods is convoluted and subject to many interesting scientific and historical biases There has been no previous examination of the region's terrestrial isopods and very few taxonomic papers of the terrestrial isopods are in English. For these reasons, and to negate the need for future or co-workers having to unravel these complexities, the history of the collection and description of terrestrial isopods in the region are reviewed and presented in detail. This is also important because the historical biases of terrestrial isopod collection within south-western Australia have had a profound influence upon regional knowledge up to this point. In order that Chapter 3 may stand alone as a taxonomic work, taxonomic methods are contained within it. The chapter concludes with a list of species that form the basis of analysis in subsequent chapters

Chapter 4 asks whether the distributions of the individual species form clear and consistent patterns. The questions are addressed by plotting and analysing the

distributions of each of the taxa examined and the subsequent construction of biogegraphical paaterns. The patterns are interpreted in association with a range of broad-scale environmental variables. Microhabitat data, where available, are examined in a descriptive way in relation to each of these patterns found. This establishes whether different taxa utilise different microhabitats in different parts of the region. Apart from the occasional need to clarify some terminology, it can be read without reference to other chapters.

Chapter 5 asks what are the important centres of terrestrial isopod richness within the region? Species richness data is construced at a range of spatial scales and determines not only diversity hotspots (alpha diversity) but also the important concept (Olson et al., 2002) of species turnover within the landscape (beta diversity). Chapter 5 can be read separately and is useful to workers who wish to compare regional patterns of species richness. Both local and regional scale patterns of richness are examined because the relationships between regional and local richness and spatial turnover are useful in explaining biogeographical patterns at both the broad and small-scale (Koleff & Gaston, 2002).

Chapter 6 provides a descriptive biogeographic model of the region based on areas of distributional and diversity similarity. It forms the basis of the final chapter which provides a historical biogeography of terrestrial isopods in south-western Australia. It recognises ten zones and describes them, in terms of their species composition, microhabitat utilisation patterns and environmental characteristics, by the use of graphs derived from the microhabitat and distributional data organised into the zones. This chapter provides a useful biogeographic summary of the region that could be read independently. However, the chapter uses some complex terminology developed in earlier chapters.

Chapter 7 provides an ecological biogeographical analysis. It asks: what ecological processes are important in creating of small-scale distributional barriers? It does this by describing patterns and properties of surface organic matter and relating them to the distributions of the taxa. The microhabitat data are analysed in order to show whether microhabitat properties differ regionally and to explain the different isopod taxa found within them. With the exception of the biogeographical model presented at the end of the preceding chapter, it is not necessary to have read any of the other chapters.

Chapter 8 asks whether it is possible to construct a historical biogeographical model, concordant with other biogeographical patterns from the region, which explains the distribution of taxa and accounts for the importance of small-scale ecological barriers. It does this by refining the biogeographical model presented in Chapter 6 and developing hypotheses to explain it. Muti-dimensional scaling is used to re-examine the concept of beta diversity at a series of scales and provide a different perspective upon, and internal validification of, the model. The chapter provides a review of the biogeography of the region, suggests how the region might be more correctly perceived and reflects upon how we might apply some the insights gained into regional ecological and historical

biogeography of terrestrial isopods to the management of the region. Much of the background to the detail it provides has been provided at various stages of the thesis but it could be read independently by someone with a good knowledge of the region and some understanding of the biology of terrestrial isopods.

CHAPTER 2

METHODS

2.1. OVERVIEW

This chapter provides an account of the construction of an ecological regional biogeography for terrestrial isopods in south Western Australia. It does not include the taxonomic methodology. This will be given in the next Chapter, which deals exclusively with taxonomical component of the work. Some specific methodology relating to the recognition of biogeographical patterns and to the development of the biogeographic model is also given, or summarised, in later chapters. It is more appropriate there because its development depended upon the results of the chapters that preceded them. The biogeography was created from material lodged at the Crustacea section of the Western Australian Museum (WAM), from the private collections of co-workers and from material collected during this study. At the end of the collection period, all material, including that graciously donated by co-workers, was registered and put into the general collection of the WAM. Appropriate licences for scientific research and the collection of isopod and plant material were obtained from the Department of Conservation and Land Management. A number of terms are developed and used throughout this and the following chapters. They are defined as they are used but are also conveniently summarised in a glossary in Section 2.9 (Table 2.4).

2.2. A FRAMEWORK FOR COLLECTION AND ANALYSIS

2.2.1. PRELIMINARY DATABASE

The first task was to assess the comprehensiveness of the WAM collection. It soon became evident that curation and sorting of specimens would form a large part of the initial work. The entire collection of terrestrial isopods at the WAM was examined. All Information relating to the specimens given on labels or in the WAM records was put on a database. At this stage, the taxonomic literature for terrestrial isopods from Western Australia was collected, reviewed and the distributions and any accompanying details of the described taxa were added to the database. All material, many of which had not been previously examined, was examined and put into new jars. Many jars contained dozens of specimens of any number of species. These had to be separated and recorded separately. At the end of this stage, which took many months, it became clear that it would not be possible to produce accurate biogeographic patterns from WAM material alone. There were many geographical gaps in the collection. The only part of the region for which there were many specimens at a meaningful geographic scale was the Perth Metropolitan area. Nevertheless, it was clear from the preliminary database that there were enough taxa distributed over a wide enough area to make a study of their biogeography worthwhile. The curation and registration of the material examined as part of this thesis accounted for a considerable portion of the time spent on this study.

Once it was clear that collection of material was necessary, the next stage of the project involved developing both a meaningful geographical study area and the means and methodology by which to collect the specimens and any data that would be valuable in explaining their distributions.

2.2.2. DEFINING A STUDY AREA

The first task was to define a study area. The area chosen had to be large enough to account for regional variation but also small enough to be able to sample at a meaningful scale in the course of a doctoral study. To reflect known biogeographic patterns, the boundaries needed to be ecological or biological rather than administrative. The selection of a study area or sites is always constrained by the time and resources available for collection of the data. It seemed that the most appropriate boundary for undertaking a biogeographical study would be the South West Botanical Province, since this represents what is a long standing natural region recognised by many schemes. This boundary, or variations of it, is present in both the flora and fauna. However, if one took the IBRA definition of this region and therefore included the seven bioregions of Geraldton Sandplains, Avon Wheatbelt, Swan Coastal Plain, Jarrah Forest, Mallee Esperance Plains and Warren, it would result in an area of some 319,343 km^2 (calculated from Table 10, Thackway & Creswell, 1995). As a comparison, this area is some 131% larger than the United Kingdom (241,600 km^2).

Clearly, it was not possible to sample this area at a meaningful scale given the time available. A smaller area was needed. The next logical step was to identify a smaller but well-defined part of this area. Since the Warren Botanical Subdistrict is important and floristically distinct (Hopper, et al. 1992) and it and the HRZ are known to be areas of important invertebrate biodiversity and centres of endemism with high conservation value they should be included. These form part of Beard's Darling Botanical District (DBD) which includes the forested part of southwestern Australia. The DBD has been used frequently in other studies (e.g. Calver & Dell, 1998a; 1998b) and is well established as a natural region. The DBD is largely synonymous with the Swan Coastal Plain, Jarrah Forest and Warren Bioregions and was shown in a Western Australian context in Figure 1.4 These three bioregions are still large in geographical terms and have an area of approximately 71 679 km^2 (calculated from Table 10, Thackway & Creswell, 1995). However, it was not considered desirable to restrict sampling to a smaller area. The validity of single bioregions as natural regions has not been established and the definition of the Jarrah Forest Bioregion is problematic as was shown in Subsection 1.5.4. It is noteworthy also that the Warren Bioregion is the smallest on the mainland of Australia and the Swan Coastal Plain is the sixth smallest. Therefore, the study area used to determine the regional biogeography presented here is the Darling Botanical District (sensu Beard, 1981b). It includes the forested part of south–western Australia (Figure 1.5) and is hereafter termed "the Region" (Figure 1.4, Darling Botanical District) and is described briefly in Section 2.10 at the conclusion of this chapter.

2.3. GETTING THE DATA

The collection of isopods was undertaken at a series of sites (Glossary). In selecting and sampling these sites, three factors were considered of paramount importance. Firstly, the logistics of covering such a large area in a relatively short time, secondly, possible biases in collection methods, and, thirdly the strongly seasonality of rainfall and moisture in the region. A stratified, rather than a random, approach to collection was needed in order to overcome these concerns. The following subsections highlight the reasons for these concerns and shows how they were overcome or minimised.

2.3.1. GEOGRAPHICAL ISSUES

To ensure that all parts of the region were well represented, it was divided into 120 localities (Glossary, p. 50 at the end of this chapter and repeated in Appendix 3). Data were then collected equitably in all localities, avoiding potential regional geographic biases. Localities are fifteen minutes latitude by fifteen minutes longitude and represent approximately equal land areas (Figure 2.1). They are numbered consecutively in rows from the northwest to the southeast of the region and coincide with Australian Topographic Survey 1:50 000 maps and the names of the sheets are used as locality names. All specimens were allocated to a locality in the database. This proved to be a very effective way of searching and organising data and underpinned some of the analysis. Isopod sampling took place at a number of sites distributed evenly throughout the localities.

Substantial WAM material from the Mount Lesueur and Stirling Range National Parks, technically outside the study area, was included in the database by means of creating supplementary localities (Glossary). Rottnest Island, lying offshore from the Perth metropolitan area, has been previously well studied (Bunn & Green, 1982) and could not be correctly considered as part of either the Perth locality or the Fremantle locality so it too was considered a supplementary locality. Original localities are numbered from 1-120 whilst supplementary ones were numbered 200-202.

To facilitate analysis at a hierarchy of geographical scales (see Subsection 2.5.2) localities were grouped to form "landscape units" (LUs) (Glossary). These units are composite areas encompassing approximately equal land area derived from a number of adjacent localities. Some landscape units coincide with areas shown on National Topographic 1:100 000 series maps and some are a combination of two maps. The appropriate map names were used as names for landscape units

Localities (A), supplementary localities, the distribution of sites within localities (B), and the representation of localities as landscape units (C) are shown in Figure 2.1. Locality names, numbers and reference to maps are given in Table 2.1 and likewise for landscape units in Table 2.2.

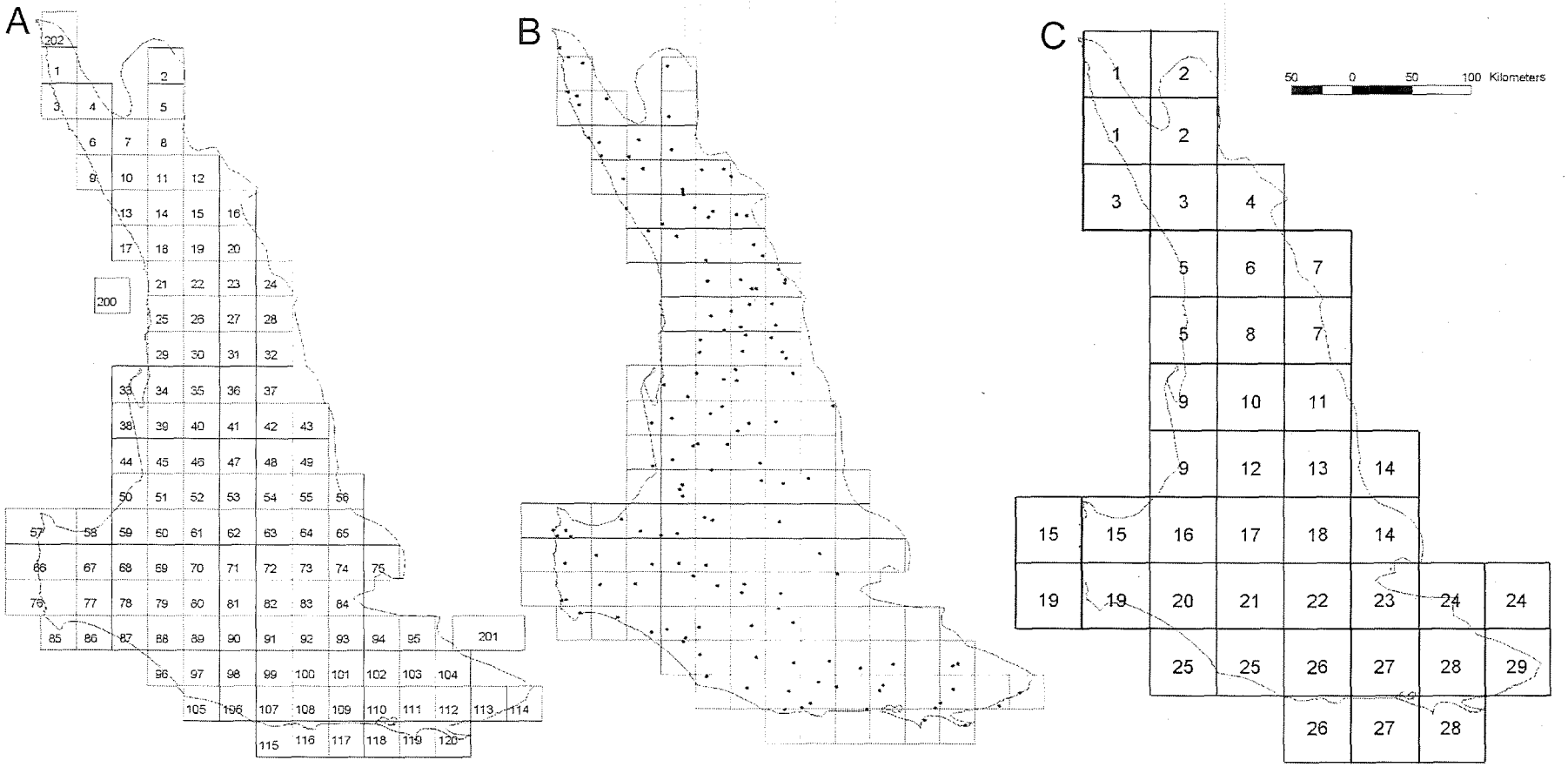


Figure 2.1. Localities, including supplementary localities (A), the stratified distribution of sampling sites (B) and composite landscape units (C). Landscape units are composite areas derived from the equitable grouping of a number of localities used for broader scale analysis of species diversity in Chapter 5.

Table 2.1.
List of localities used to determine the sampling strategy. Localities names are taken from the Australian Topographic Survey, 1:50 000 maps.

#	Map	Locality	#	Map	Locality	#	Map	Locality
1	1937 - III	Hill River	42	2232 – III	Dwarda	83	2229 – I	Lake Clabburn
2	2037 - II	Tanche	43	2232 – II	Congelin	84	2329 – IV	Uannup
3	1936 – IV	Cervantes	44	2031 – IV	Lake Preston	85	1929 – III	Leeuwin
4	1936 – I	Wongonderrah	45	2031 – I	Harvey	86	1929 – II	White Point
5	2036 – I	Lake Dalaroo	46	2131 – IV	Tallanalla	87	2029 – III	Lake Jasper
6	1936 – II	Walyengarra	47	2131 – I	Nalyerin	88	2029 – II	Charnwood
7	2036 – III	Yatheroo	48	2231 – IV	Quindanning	89	2129 – III	Pemberton
8	2036 – II	Capitela	49	2231 – I	Williams	90	2129 – II	Deeside
9	1935 - I	Lancelin	50	2031 – III	Bunbury	91	2229 – III	Lake Muir
10	2035 - IV	Bidaminna	51	2031 – II	Burekup	92	2229 – II	Quindinup
11	2035 - I	Mindarra	52	2131 – III	Collie	93	2329 – III	Cybellup
12	2135 – IV	Wannamal	53	2131 – II	Muja	94	2329 - II	Geekabee
13	2035 – III	Moore River	54	2231 – III	Darkan	95	2429 – III	Tenterden
14	2035 – II	Gingin	55	2231 – II	Hillman	96	2028 – I	Meerup
15	2135 – III	Chittering	56	2331 – III	East Arthur	97	2128 – IV	Northcliffe
16	2135 – II	Dewars Pool	57	1930 – IV	Yallingup	98	2128 – I	Shannon
17	2034 - IV	Yanchep	58	1930 – I	Busselton	99	2228 – IV	Mount Johnston
18	2043 - I	Muchea	59	2030 – IV	Capel	100	2228 – I	Mount Roe
19	2134 – IV	Jumperkine	60	2030 – I	Donnybrook	101	2328 – IV	Rocky Gully
20	2134 – I	Toodyay	61	2130 – IV	Wilga	102	2328 – I	Kwornicup
21	2034 – II	Perth	62	2130 – I	Evans	103	2428 – IV	Mount Barker
22	2134 – III	Mundaring	63	2230 – IV	Blackwood River	104	2428 – I	Porongurup
23	2134 – II	Chidlow	64	2230 – I	Moodiarrup	105	2128 – III	Gardner River
24	2234 – III	Mount Observation	65	2330 – IV	Boscabel	106	2128 – II	Wainbup
25	2033 – I	Fremantle	66	1930 – III	Cowaramup	107	2228 – III	Deep River
26	2133 – IV	Kelmscott	67	1930 – II	Whicher	108	2228 – II	Mount Frankland
27	2133 – I	Beraking	68	2030 – III	Cambray	109	2328 – III	Owingup
28	2233 – IV	Coolaring	69	2030 – II	Ballingup	110	2328 – II	Denmark
29	2033 – II	Wellard	70	2130 – III	Bridgetown	111	2428 – III	Redmond
30	2133 – III	Jarrahdale	71	2130 – II	Boyup Brook	112	2428 – II	Oyster Harbour
31	2133 – II	Yaganing	72	2230 – III	Dinninup	113	2528 – III	Two Peoples Bay
32	2233 – III	Luptons	73	2230 – II	Qualeup	114	2528 - II	Manypeaks
33	2032 – IV	Mandurah	74	2330 – III	Kojonup	115	2227 – IV	Saddle Island
34	2032 – I	Pinjarra	75	2330 – II	Cablecatup	116	2227 – I	Rame Head
35	2132 – IV	Dwellingup	76	1929 – IV	Karridale	117	2327 – IV	Parry Inlet
36	2132 – I	Duncan	77	1929 – I	Rosa	118	2327 – I	Ratcliffe
37	2232 – IV	Wandering	78	2029 – IV	Jalbarrgup	119	2427 – IV	Torbay
38	2032 – III	Lake Clifton	79	2029 – 1	Carlotta Brook	120	2427 – I	Albany
39	2032 – II	Hamel	80	2129 – IV	Wilgarup	200	*	Rottnest Island
40	2132 – III	Nanga	81	2129 – I	Yerraminnup	201	*	Stirling Range
41	2132 – II	Marradong	82	2229 – IV	Tonebridge	202	*	Lesueur

Table 2.2.
List of landscape unit numbers and names. Map numbers and names are taken from National Topographic Map Series, 1:100 000, Edition 1, 1975.

#	Map	Localities included	NAME	#	Map	Localities included	NAME
1	1936/7	1, 3, 4, 6, 9, 202	Hill River	16	2030	59, 60, 68, 69	Donnybrook
2	2036/7	2, 5, 7, 8	Dandaragan	17	2130	61, 62, 70, 71	Bridgetown
3	1935/2035	9, 10, 11, 13, 14	Gingin	18	2230	63, 64, 72, 73	Dinninup
4	2135	12, 15, 16	Chittering	19	1829/1929	76, 77, 85, 86	Leeuwin
5	2033/4	17, 18, 21, 25, 29, 200	Perth	20	2029	78, 79, 87, 88	Donnelly
6	2134	19, 20, 22, 23	Wooroloo	21	2129	80, 81, 89, 90	Manjimup
7	2233/4	24, 28, 32	Northam	22	2229	82, 83, 91, 92	Tonebridge
8	2133	26, 27, 30, 31	Jarrahdale	23	2329	84, 93, 94,	Frankland
9	2031/2	33, 34, 38, 39, 44, 45, 50, 51,	Bunbury	24	2429/2529	95, 201	Tambellup
10	2132	35, 36, 10, 41	Dwellingup	25	2231	96, 97, 98, 105, 106	Northcliffe
11	2232	37, 42, 43	Crossman	26	2227/8	99, 100, 107, 108, 115, 116	Deep River
12	2131	46, 47, 52, 53	Collie	27	2327/8	101, 102, 109, 110, 117, 120	Denmark
13	2231	48, 49, 54, 55	Darkan	28	2427/87	103, 104, 111, 112, 119, 120	Albany
14	2330/2331	56, 65, 74, 75	Kojonup	29	2528	113, 114	Manypeaks
15	1830/1930	57, 58, 66, 67	Busselton				

2.3.2. COLLECTION METHOD ISSUES

To ensure comprehensive regional coverage of data, the collection was stratified with the intention of having at least one site in each locality. However, this was largely dependent upon the time available and the existence of suitable sites within a locality. The 146 sites with their chronological numbers are shown in Figure 2.2. Sites 1-30 were distributed evenly throughout the region. These, although no less useful in the data they contributed, facilitated the development of a search image and identification of microhabitat types throughout the region. It was considered likely that collecting would become more proficient as the study progressed. Therefore the first thirty sites were distributed equitably throughout the region both to avoid potential biases in the data and to understand how microhabitat types might differ throughout the region. Collecting methods were refined at these sites and were then applied to the remaining 116 sites.

2.3.3. SEASONALITY ISSUES

It was not possible, due to the amount of land that had to be covered, to sample all sites in a range of seasons. Therefore, care had to be taken in order to avoid seasonal biases. There is a strong seasonal component to the activity of terrestrial isopods with both temperature and rainfall being important determinants of population dynamics (e.g. Nair, Fadiel & Mohamed, 1989; Ma, Dudgeon & Lam, 1991). In Mediterranean environments in particular, breeding activity can coincide with spring rains, congruent with a rise in relative humidity, atmospheric temperature, and day length (Aljetlawi & Nair, 1994).

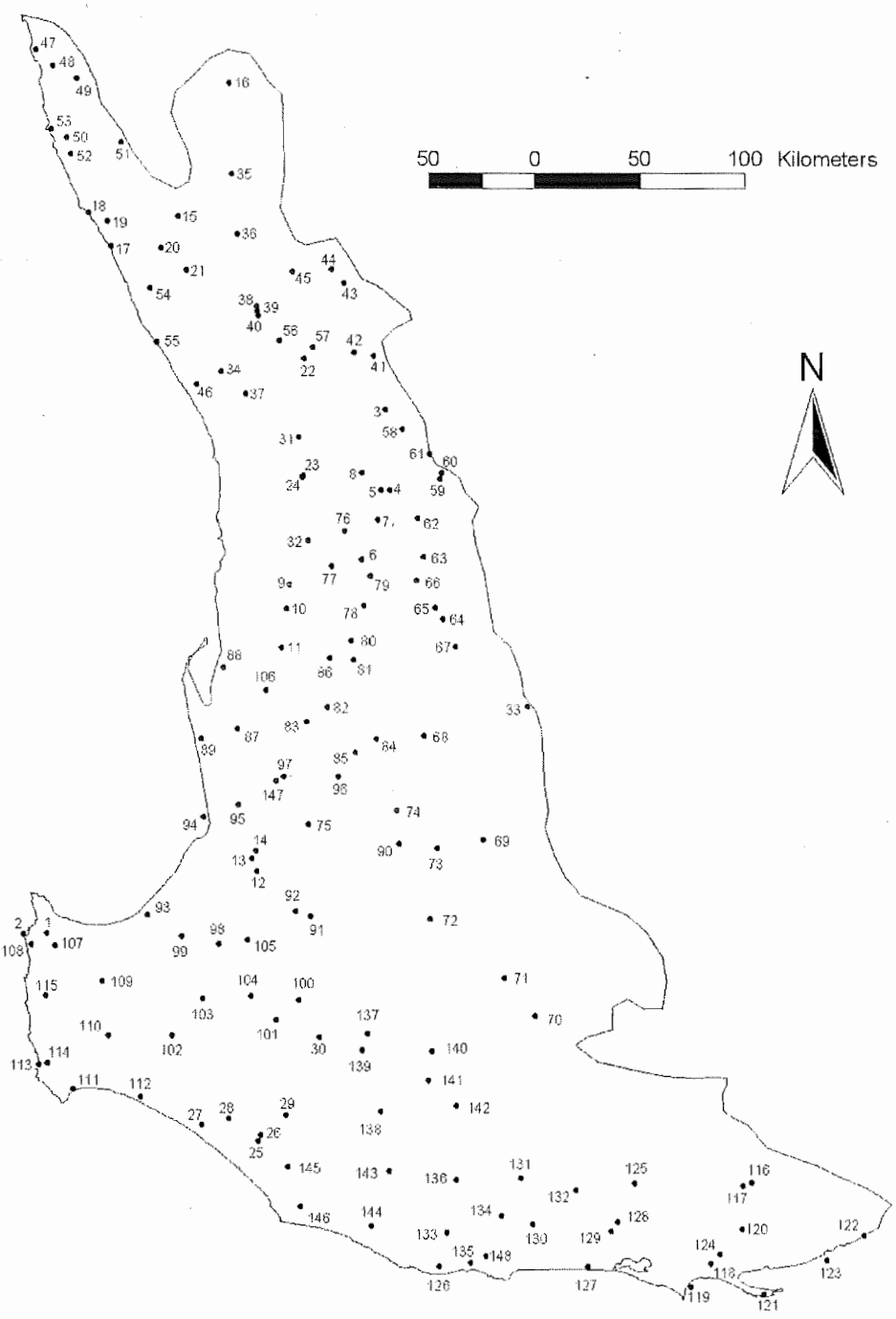


Figure 2.2. The location of the 146 sites sampled during this study. Site details are given in Appendix 1a. The first thirty sites are spread throughout the region and subsequent sites follow a southward movement to avoid seasonal biases.

A valuable insight into the seasonal activity of epigean invertebrates at three sites within the study area was presented by Koch and Majer (1980) and Majer and Koch (1982). The earlier of these papers presented data about the seasonal activity of seven isopod taxa at three localities, each in a different bioregion. These data were extracted from Koch and Majer (1980) and are shown in Figure 2.3. Terrestrial isopods conformed well to seasonal trends observed for decomposer activity at the three sites studied. Activity was closely associated with the wetter months in Perth (Swan Coastal Plain Bioregion) and with the wetter months, late spring and early summer, in Dwellingup (Jarrah Forest Bioregion). Activity at Manjimup, in the much wetter Warren Bioregion, occurred in the warmer months. Activity of surface-active decomposers was positively correlated with rainfall and the relative humidity of the previous month at Perth and with the previous month's rainfall at Dwellingup. In contrast to Perth, decomposer activity at Manjimup was positively correlated with both mean temperature of the month of collection and of the previous month, and negatively correlated with the relative humidity of the month of collection. Since Isopods reflected the overall trends shown by decomposers, we would expect to find different patterns of seasonal activity in different areas of the south-west. In Mediterranean climates of south-western Western Australian forests, there may be marked seasonal differences in isopod activity, dependent largely upon rainfall and latitude.

A summary of Koch and Majer's (1980) isopod data were also given by Majer and Abbott (1989). They suggested that the duration of decomposer activity was likely to increase from north to south. In the light of these observations, the sensitivity of terrestrial isopods to the seasonal availability of moisture was considered to be the most important factor in determining a temporal sampling strategy. Seasonal conditions needed to be optimal at all sites to ensure that the full range of species could be located and caught. If moisture conditions had differed greatly, over even the smallest geographic area, then isopods would not have had an equal chance of being collected throughout their range.

Figure 2.2 showed the location and chronological numbering of the sites sampled during this study. Sites 31-146 were those sampled after methods had been refined, and represent a movement southward. This was done purposefully for the ecological reasons outlined above and because sites in the north of the region were observed to dry rapidly and much sooner than those further south. The overall optimum time to sample was considered to be when temperatures warmed but before sites dried considerably. This equated to late winter in the northern parts of the region, early spring in central northern and eastern parts, late spring in central southern parts and early summer in the far south. This created potentially similar moisture conditions in all sites and avoided strong seasonal biases. Moisture conditions were not expected to vary more between sites in different parts of the region than they would within the sites themselves.

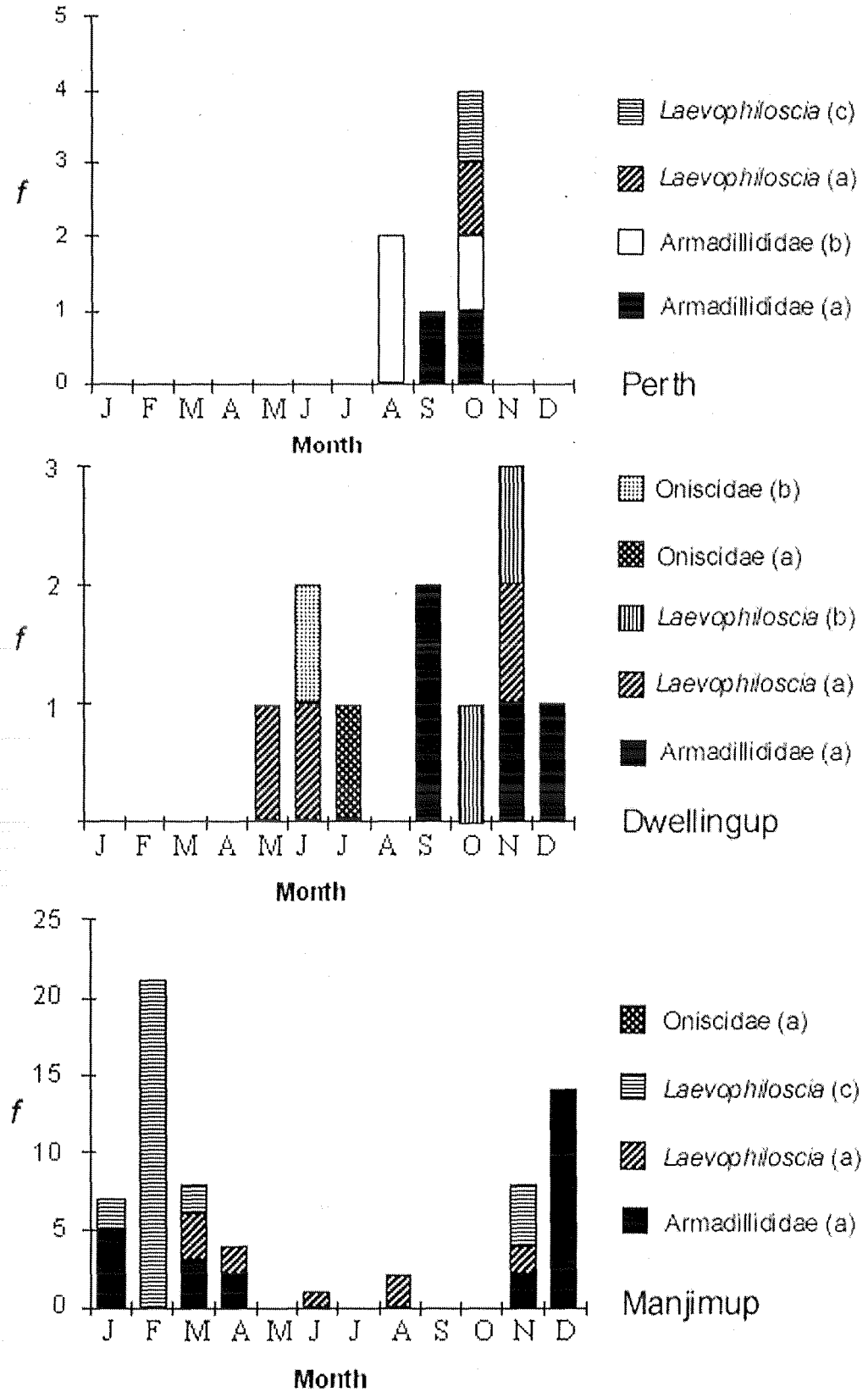


Figure 2.3. The frequency (f) of terrestrial isopods collected from pitfall traps over seven days in each month March 1976 to February 1977. Sites were at Reabold Hill (Perth, Swan Coastal Plain Bioregion), Curara block (Dwellingup, Jarrah Forest Bioregion) and Dingup block (Manjimup, Warren Bioregion). Data extracted and plotted from Koch and Majer (1980).

2.4. COLLECTION SITES

The final pattern of sites within the framework of localities was shown in Figure 2.1 and chronologically in Figure 2.2. The Perth metropolitan area was already very well represented in the WAM collection and so this was not sampled during this study. Whilst providing for a comprehensive coverage, it was also considered preferable to concentrate sampling more in areas that had not previously been sampled. The details of how sites were selected in each of the localities are described in the following subsection. Four sites were excluded from analyses in Chapter 6 onwards because of the use of non standard methodlogy. Details of these and all sites is given in Appendix 1.

2.4.1. SITE SELECTION

Stratified field sampling occurred between July 15, 1998 and January 28, 1999. Appendix 1a presents a chronological list of site names sampled and also gives a brief description of each site. These are essentially field notes and are presented in a very subjective form. Site description included something about the vegetative character of the site, important physical features and any observations that made the site potentially different. All plant names used are common names. No plant material was collected for identification, and observations were made from personal knowledge gained through previous studies or from the literature. Terms such as "open", low" and "sparse" are highly subjective and relative terms. Since the data presented were not used in any flonstic analysis, they have been repeated here purely for the purposes of a comprehensive historical documentation. Since the body of specimens collected dunng this work is considerable, some information, even with perceived bias of the collector, is probably better than none. The tenure of sites was noted from field observation or extracted from CALM 1:50,000 Land Management Series maps. It was correct at the time of sampling but it should be recognised that some of the sites these may now have different tenure or are likely to in the near future (Conservation Commission, 2002). A summary of the vegetation associations using the descriptions given by Beard (1981b), obtained by later GIS analysis, is given in a separate table in Appendix 1b.

Within each locality, sites were chosen with reference to a number of criteria. Firstly, the site should have native vegetation. Areas of farmland, urban areas and other large disturbances were avoided. Preference was given to areas managed for conservation, and National Parks and Nature Reserves were always sampled where they were present. Other types of conservation reserves were also sampled where necessary. Areas recently disturbed and or burnt[6] were avoided where

[6] Searching these areas is largely fruitless anyway

possible The goal was to maximise the number of potential microhabitat possibilities within a site

Up to three sites were sampled in some localities and none in seventeen of the others This is because there was no adequate native vegetation in these localities This is very much the nature such is the nature of the Western Australian wheatbelt. Many of the nature reserves in these areas that were sampled represented only semi-natural vegetation Much of the remnant vegetation is also on private land (which was logistically impossible to sample at this scale of the work) or on road verges which are hardly representative for constructing a biogeographic model Given obvious time constraints with such a large study area, it was considered best to concentrate on localities where suitable sites existed

The final selection of sites incorporated all available landforms within the locality and was based upon a balance between logistics and randomness Features such as creeks, riparian zones, slopes, gullies and rocky outcrops were included within a site where possible Final selection was made in consultation with the land management agency (CALM) at the appropriate district or regional office All necessary disease risk and entry permits were obtained at this stage and management authorities were informed of the sites likely to be sampled.

Two principal methods of sampling were employed, hand collecting and extraction by Berlese funnels The details of these methods are outlined in the following sections At two sites (147 and 148), only Berlese funnels were employed. An abbreviated form of the site names is shown in Appendix 1a Therefore, these may differ slightly from the names given in the lists of material examined in Chapter 3 So that material examined may be accurately cross-referenced to the site from which it was collected, decimal latitude and longitude coordinates are included for each site

2.4.2. SAMPLING PROTOCOL

Sites were usually sampled by two persons Occasionally, at sites close to Perth, where travelling time was less and therefore more time could be allocated to field sampling, sites were sampled by one person. Site data were recorded at arrival and Global Positioning System (GPS) coordinates were obtained by use of a Garmin GPS45 Personal Navigator The GPS co-ordinates given in Appendix 1a and for taxa in Chapter 3 (sections 3 7-3 17) are for the centre of a site

Sites were standardised in that they extended up to 200 metres from their central point Therefore, all sites were about 12 5 ha in size. Sites were sampled for a minimum of three hours Sites with greater variation in landform, vegetative structural complexity or a greater number of potential microhabitat types present were sampled for longer Sites were sampled until no new microhabitat types were

identified and each had been samples for at least thirty minutes. No more than three sites were sampled in one day. Time, date and weather conditions were recorded as well as pertinent sites characteristics such as vegetation type, slope and aspect. Slope was measured subjectively on a scale of 0 (flat) to 5 (very steep) and the down-slope direction as determined by compass bearing was taken as the aspect. At some sites, such as dune systems or some rocky biotypes, topography within the site made the concept of aspect meaningless. The slope of these sites is shown in Appendix 1a as variable (V). Potential microhabitat types were identified at each site and searched systematically.

2.4.3. ISOPOD SAMPLING

General methods for collecting terrestrial isopods have been described by Sutton (1972) and Hopkin (1991). These methods were only partially transferable to southwest Australian landscapes where terrestrial isopods can sometimes be extremely hard to find. Oniscidea literature concerning isopods for the south-western Australia does not include such methods. Much of the time at a site was spent searching for specimens and a lesser amount collecting them and associated data. Considerable time was spent developing methods and techniques for collecting before the stratified sampling began. Therefore, they are recorded here in detail and also illustrated for the benefit subsequent workers.

Isopods were searched for and collected primarily by hand. Pitfall traps were not used since they are not considered entirely effective (Sutton, 1972) and because it was not possible to visit sites twice. Litter was sorted and picked both in situ and after transferring it to white trays. The use of white trays aided both the sighting and capture of specimens. Specimens were caught by aspirator (pooter). This method was preferred because it proved, after practice, the most effective method and because specimens were not damaged Specimens too large for the pooter tube were picked up by forceps Specimens were immediately transferred to clear 30 mL glass jars with lids, consecutively and uniquely numbered according to each discrete microhabitat. Labels were put in each of the jars giving the site number date and microhabitat detail Live specimens were routinely inspected through the glass jars for the presence of pleopodal lungs At the conclusion of site sampling, 70% ethanol was added to jars to preserve the specimens. Plate 2 1 shows the range of collection and preservation equipment used

Logs and stones were turned and logs broken apart using a hammer and crowbar Diggings were made in the soil under logs with a trowel and soil and logs samples were sorted in white trays to more easily locate specimens. Tree bark was removed by chisels and the boles of trees searched. White sorting trays were used to catch any animals falling from trees during this process.

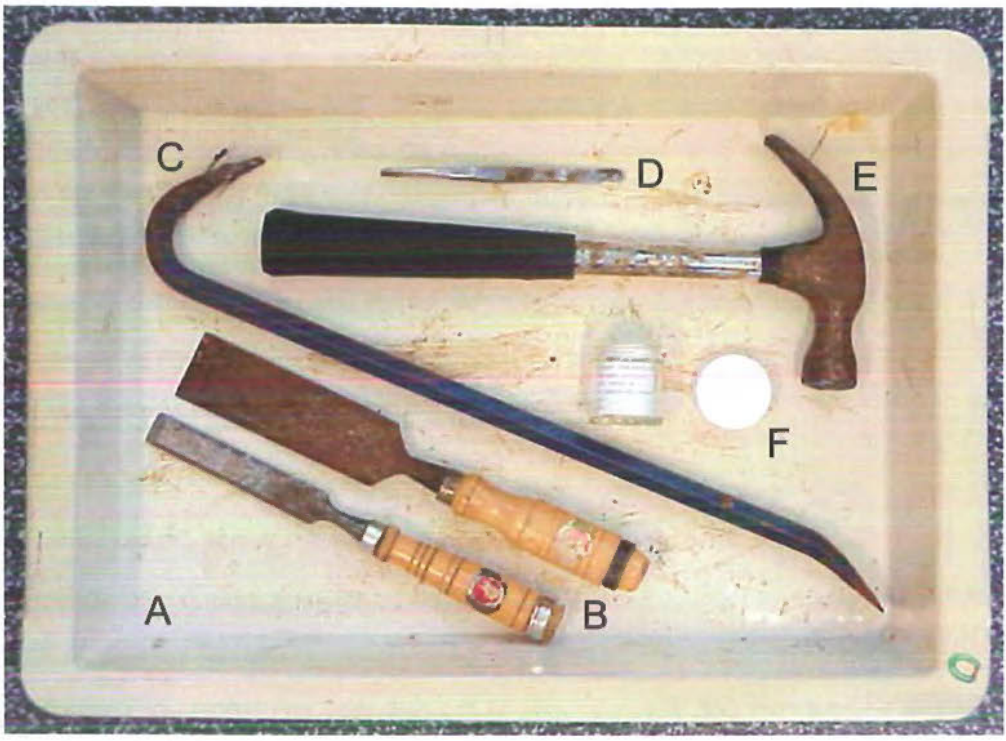


Plate 2.1. Items (well) used in the collection of terrestrial isopods. A white tray external (50 x36 cm) (A), chisels of varying size (B), crowbar (C), forceps (D), hammer (E) and 30 mL storage jar with label inserted (F). See text for detail of the methods.

Plate 2.2. Litter and soil sampling equipment. Two diameters of PVC pipe were used to sample litter (A) and soil (B). Litter and soil samples were stored in durable sealed plastic bags to prevent moisture loss. See text for detail of the methods.

2.4.4. MICROHABITAT SAMPLING

Wherever isopods were found, a sample of the microhabitat was taken from the exact position where the specimen was collected. All litter samples were from woody vegetation where litter had fallen naturally and accumulated upon the soil, logs or other substrate. Wetlands with sedges, caves and aquatic habitats were not sampled during this study. Therefore, a microhabitat sample could be any of the following:

a sample of the leaf litter and soil for specimens collected from leaf litter on soil;

a sample of litter for specimens collected from litter occurring on rocks or logs;

a sample of soil for specimens collected from under logs;

a sample of wood for specimens collected from in logs;

a sample of log bark for specimens collected from under bark on logs; or

a sample of tree bark specimens collected from under the bark on trees.

Ths collection of litter samples was standardised by using 105 mm internal diameter PVC pipe. The pipe was cut to approximately 350 mm lengths and one end sharpened. The pipe was placed in the litter, and pushed and twisted downward until the sharpened base of the pipe was resting on top of the A horizon of the soil. The litter contained within the pipe was removed by hand leaving an exposed mineral soil. The litter was put immediately into a durable plastic bag and sealed to prevent moisture loss.

Soil samples were taken in a similar way using 45 mm internal diameter pipe as a corer. The corer was pushed into the soil up to depth 100 mm, depending upon the penetrability of the soil. Soil samples were removed from the corer and immediately placed in an identical bag to prevent water loss. Soil and litter equipment was cleaned and dried between uses. Soil and litter corers and a sample bag are illustrated in Plate 2.2.

Samples of wood, log and tree bark of approximately equal area or volume were removed using a chisel. These varied inherently due to the differing characteristic of each of the logs of each tree species. Samples were also sealed in plastic bags immediately to prevent water loss Labels were added to microhabitat samples and numbered consecutively. The sample number was given a postscript of "L", "S" or "W" depending on whether the sample was of litter, soil or wood The samples were cross-referenced with the isopod collection jar labels, and documented on the site datasheet.

2.4.5. BERLESE FUNNELS

Litter, in addition to that sampled by the methods in the preceding subsection, was removed from randomly selected sites. Sampling was undertaken during periods

of four of five days at a time. In each of these collecting events, litter was collected for processing by Berlese funnels. The rationale behind the use of the funnels was to increase the likelihood of collecting all the litter dwelling taxa at a regional level It was a complementary method to litter sorting and was not designed to be used as the basis for a statistical comparison between samples. Litter was collected from five randomly selected sites during each collecting trip and stored in 42 L plastics bins with tight (but not airtight) fitting lids. Litter was collected at various spots within a site and the volume collected varied depending upon litter abundance at the site being sampled, but was normally about 35 L. At the end of the collecting trips, the litter was added to the Berlese funnel. Six funnels, approximately 50 x 50 cm and 60 cm deep, belonging to the WAM were kindly loaned by M. S. Harvey. They were heated by four 25 W electric light bulbs. It was not possible to continually monitor the funnels because extraction occurred while the next field trip was being undertaken. Consequently, no temporal temperature gradient was used. Funnels operated at maximum heating capacity for approximately 2 weeks or until litter was thoroughly dry. Specimens were collected in 70% ethanol in glass jars, and funnels were emptied and cleaned prior to adding litter from subsequent sites. Collection jars were sorted and isopods removed using a dissecting microscope at various magnifications. Jars were sorted until no further isopods could be found.

2.5. DETERMINING PATTERNS

2.5.1 BIOGEOGRAPHY

The biogeographical patterns found in Chapter 4 were determined by examining the distributions of all the relevant taxa (see Section 3.20). Distribution maps for each taxon were prepared in ArcView v3.2 (ESRI, Redlands, California) to the same scale, to enable accurate matching by means of overlays. Concordant distributions among taxa were recognised and classified according the feature of the pattern they presented. More detailed methods and specific criteria for the each of the biogeographical patterns recognised are given later in Section 4 2 Microhabitat graphs were prepared using classified data for one or more taxa within each pattern. Details are also given in Section 4.2.

2.5.2 DIVERSITY

Following the biogeographical analysis, patterns of species diversity were examined in Chapter 5. These were created by plotting the number of taxa found at each of three inventory scales, point, local and landscape (see Section 5 2 for the rationale underpinning these). At the smallest scale, the number of taxa occurring at each of the sites shown in Figure 2.2 was plotted using ArcView v3.2. At the two larger scales, the number of taxa occurring in each locality and

landscape unit (see Figure 2.1) was extracted from the database. This was possible because, as well as decimal latitude and longitude coordinates, each record had been previously assigned to both a locality and landscape unit. Schematic maps were then prepared showing the number of taxa recorded for each of the localities and landscape units. The same process was repeated for the numbers of records from each locality and landscape unit for the analysis shown in Subsection 5.6.1.

2.6. CONSTRUCTING THE MODEL

2.6.1 PRELIMINARY BIOGEOGRAPHIC MODEL

The biogeographic model created in Chapter 6 was based upon the grouping of localities with similar taxa and richness. The boundaries were drawn at the locality scale, and this is ultimately reflected in square boundaries shown in Figure 6.1 Each locality was grouped with, or separated from its neighbour based on firstly, the overall richness of the locality and, secondly, the taxa found within it. Abrupt changes in local diversity indicated the limit of the geographical range of many species and provided obvious boundaries at the locality scale. Therefore, boundaries are only likely to be accurate at the locality scale.

While the creation of these boundaries involved a large degree of subjectivity, they were, in many respects, intuitively obvious. The patterns were derived from the systematic and objective plotting of individual species' distributions, grouped into patterns of parapatric species and upon the collation of richness data at an appropriate geographical scale. Each of resulting ten geographical units delineated by the construction of the model was called a zone. Each record in the database was then coded according to the Zone in which it occurred. Histograms were created showing the number of taxa found in each zone classified according to the biogeographical pattern to which they contributed. The microhabitat data, previously analysed to illustrate the biogeographical patterns, were re-analysed to show the microhabitat utilisation within each of the zones of the model. The geographical area of the zones was calculated using ArcView 3.2.

2.6.2 REVISED BIOGEOGRAPHIC MODEL

A "fine tuning" of the boundaries of the biogeographic model delineated previously was undertaken in the final chapter. This was designed so that the boundaries reflected the distributions of indicative taxa rather than the inflexible boundaries of the locality-scale analytical framework. This was achieved by the following methods. All species distributions, in the form of overlays, were plotted at the same scale and placed over the biogeographic model shown in Figure 6.1. A hierarchical series of delineations was then made. A first order delineation recognised two subregions, second order delineations divided the subregions into

four macrozones, and finally, third order delineations divided the four macrozones into nine zones.

The first delineation recognised a major faunal break by separating the northern taxa from the higher rainfall taxa found further south. This break was first estimated to be at the southern limit of the taxa described in Northern Patterns (Chapter 4) but was then iteratively refined by overlaying and the limits of distribution of all taxa. The resultant line reflected more accurately common distributional boundaries and created two subregions, each with the highest number of endemic taxa that could be created by drawing a single line anywhere within the region.

A similar process was conducted within each of the subregions defined by delineating the faunal break. Lines were drawn to create four macrozones of the maximum possible endemism within each subregion. Initially, these lines reflected bioregional specificity shown by Northern Patterns and by the obvious high richness found in the southern forests. As with the delineation of the major faunal break, these boundaries were iteratively adjusted by examining the individual distributions of the species in question.

Finally, the concordant distributions of key species were used to delineate important pockets of small-scale endemism within the macrozones A presence/absence matrix of the species occurring in each of the subregions, macrozones and zones, was constructed. Multi-Dimensional Scaling ordinations two geographical scales (methods in Section 2.8) were undertaken to examine the valiadity of the model and to examine the faunal relationships among the zones.

2.7. UNDERSTANDING MICROHABITAT

In order to determine whether the presence of terrestrial isopod taxa was related to particular microhabitat properties, a range of analyses were carried out.

2.7.1. MOISTURE CONTENT

Soil and litter samples were air-dried to obtain an estimate of field moisture content. Samples were removed from plastic bags in the laboratory and transferred to pre-dried paper bags of a known weight. Excess moisture and condensation, evolved through sweating of the litter, were removed from the plastic bags by drying with paper towels of a known dry weight. This was weighted, along with the litter sample, to determine overall moisture loss. Air-drying of litter and soil occurs at between 60-105°C, depending upon the purpose of the study. In this case, samples were weighed and air-dried at 95°C for a minimum of 48 hours and immediately reweighed. Moisture loss was calculated as the difference in the two weights, minus the known weights of the towels and bags, and expressed as follows:

Air-dry moisture (%) = (Weight of Moisture (g) x 100)/Weight of air-dry sample

Following drying, soil samples were stored in dry sealed plastic jars (Rayment & Higginson, 1992) for later analysis. Litter samples were retained in the paper bags.

2.7.2. LITTER PROPERTIES

The weights (g) of litter samples of the known sample area (78 5 cm^2) were extrapolated to give litter density in kg/m^2. Litter samples are routinely analysed for fractional content (e.g. O'Connell, 1985) and for composition (e.g. Grigg & Mulligan, 1999) and vary according to nature of the study. In this case, litter fractions were determined by sieving air-dry litter. Various sieve diameters were trialled and it was found that sieve diameters of 5 mm and 13 mm gave a good separation of material into the following fractions: fine (< 5 mm); medium (>5 mm <13 m); and, coarse litter (> 13 mm).

Following sieving, the weight of each fraction was recorded and the coarse fraction of each sample was sorted and divided into the following components: leaf; bark; wood; fruit; and, other. The weight of each component was then recorded. Some litter samples were found to contain small rocks or other non-organic components. In this case, the weight of these components was recorded and litter weights and density were adjusted accordingly.

2.7.3. SOIL PROPERTIES

Soil moisture is considered a universally important factor in the distribution of terrestrial isopods (e.g. Warburg 1993; Nair & Aljetlawi, 1993; Fallaci et al., 1996). Because of the relationship between soil moisture and a number of soil properties, these properties were investigated to determine firstly, their relationship to soil moisture and secondly, to see if the distributions of terrestrial isopod themselves might be related to them. All soil analysis was carried out on the < 2 mm fraction (Rayment & Higginson, 1992; Rowell, 1994). Large peds were broken up and obvious concretions and rock fragments removed prior to sieving. Following sieving, the < 2mm fraction was returned to the airtight container. Due to the number of samples (335), the following analyses were carried out on air-dry soil for speed and convenience unless stated. This is common practice (Rayment & Higginson, 1992) and is acceptable, since a relative measure of the samples was required, and not comparisons with the other findings. Except for particle size analysis, all analyses were conducted on each of the individual soil samples. In order to give a more accurate measure of soil particle size, the samples from each site were grouped. This created a much larger soil sample, reduced the number of samples by a third, reduced error and ultimately gave a more accurate indication of soil texture.

The residual coarse fraction of the soil (> 2mm) was analysed for component parts such as rock fragments, pisolites, charcoal and coarse organic matter. However, since these results are not reported, the methods are not given here.

2.7.3.1 Electrical conductivity and pH

Soil pH and electrical conductivity (EC) as an estimate of the concentration of soluble salts in the soil, were carried out on 1:5 soil:water extracts. In each analysis, 5 g of soil was dissolved in 25 mL of deionised water. Soil pH was measured both in soil water suspension and in 0.01M calcium chloride extract. Measurements were made with hand-held meters following the methods of Rayment and Higginson (1992 pp. 15-19).

2.7.3.2 Loss on ignition

Soil organic component is important in increasing the nutrient and moisture holding capacity of soils (Plaster, 1995). Therefore, loss on ignition (LOI) was used to determine an approximation of soil organic carbon content. Samples of soil used for determination of LOI were oven dried at 105°C for 12 hours prior to analysis. A 10 g homogenous subsample of each soil sample was finely ground and placed in crucible of a known weight. Samples were burned in a furnace at 500°C for at least twelve hours following the methods of Rowell (1994). Samples were reweighed and loss on ignition was determined according to the following:

LOI = 100 x (weight of oven dry soil – weight of ignited soil)/ mass of oven dry soil.

Results were expressed as g per 100 g oven dry soil or LOI %.

When oven-dry soil is heated to 500 g, organic matter is burned off but there is also further water loss from the soil. Soils that contain appreciable quantities of clay and sesquioxides lose "structural" water at between 105 and 500°C. Therefore LOI is only an approximate measure of soil organic carbon. It will be overestimated in heavily textured soils but is more accurate in sandy soils (Rowell, 1994). The number of samples, and the capacity to process multiple samples, made this the only viable method.

2.7.3.3 Particle size analysis

Sand was separated from silt and clay by sieving. Four sand fractions were obtained, but the content of silt and clay was not separately determined due to time constraints and the need to assess the more valuable data from the sand treatment. Endecotts stackable sieves with apertures of 500, 250, 125 microns were used for sieving. Sieves were mechanically agitated for 15 minutes, after which weights were determined for each fraction. Percentages by weight for each fraction were calculated and the data were classified according to the following: very coarse sand (> 500 microns), coarse sand (< 500 micron > 250 micron);

medium sand (< 250 micron > 125 micron); and, fine sand, slit and clay (> 125 micron).

2.7.3.4 Total calcium content

The availability of calcium is important to the functioning of terrestrial isopods. Besides copper, it is one of the principal elements to be found in large amounts in them (Zimmer, 2002). Calcium content of all soil samples was determined by Atomic Absorption Spectrometry. A homogenous 0.4 g soil sample was analysed following digestion in 2 mL of 70% perchloric acid ($HClO_4$) at 180°C for two hours in a block digester. On cooling, 18 mL of deionised water was added giving a dilution of 1:50. Samples were then shaken and left for 72 hours to settle.

Standards were prepared at 10, 20, 50, 100, 200 and 1000 ppm. Four calibrations were made: (1) 10, 20, 50 ppm; (2) 10, 20, 50 100 ppm; (3) 100, 200 ppm; and, (4) 200, 1000 ppm. Samples were read on an atomic absorption spectrophotometer (SPECTR AA) using each range of calibration standards. Parts per million values for Ca^{2+} ions in the samples were obtained for the optimum readings. Samples that had a total calcium content beyond the optimum range of the equipment were further diluted and read again until a reading was obtained. Parts per million values were then calculated by multiplying the PPM values by the dilution factor.

2.8. DATA MANAGEMENT AND ANALYSIS

Data were stored in a DBF format database and manipulated using Microsoft FoxPro V. 2.6. This software was selected because it was the WAM standard at the time of the research (Berry & Christie, 2002) and was therefore interchangeable with WAM databases. Fields included taxonomic, geographic, microhabitat, collector and site information. Latitudes and longitudes for Museum material were obtained using the WAM gazetteer and from maps. Latitude and longitude coordinates were converted to decimals and all data were checked for accuracy by plotting in ARCVIEW GIS V 3.2. Records (Glossary) were created when different taxa occurred at a different site, on a different date, from a different sample within the same site, from a different microhabitat or by a different collection method or collector. All records were rated for geographical accuracy as outlined the Table 2.3. The geographical accuracy of records was upgraded continually.

Table 2.3.
Categorisation of geographic data accompanying specimens.

Initial Category	Label Description	Examples	Final Category	Accuracy
1 - Exact	Full latitude and longitude coordinates present and given OR from an exact location such as a site, cave etc. for which coordinates are known from other records within the database.	Specimen in a vial with a label that includes degrees and minutes and seconds or full AMG. Latitude and longitude coordinates given as GPS coordinates. Assumed to be accurate.	1	>1 km
2 - Precise A	Partial latitude and longitude coordinates or AMG reference present. Coordinates calculated personally to the nearest minute from 1:100000 maps (or better).	Specimen in a vial with a label that includes degrees and minutes or partial AMG. Assumed to be accurate.	2	1 km
3 - Precise B	Latitude and longitude coordinates determinable from data, from detailed maps within accompanying published papers or determined from maps at a scale of 1:100000. Localities or sites specific enough to allow determination by gazetteer.	Detailed diagram or notes with a published paper or label describing locations of sites. Road junctions, forest block numbers and names, distances on known roads from major towns or landmarks. Subsequently plotted on appropriate scale maps. Landmarks, lakes or other features determinable by gazetteer.	3	1 km
4 - Specific A	Specific localities, given by collectors which cover a large area or where sites are grouped. Latitude and longitude coordinates determinable by gazetteer or by 1:100000 map or from other records. Additional detail given.	Published paper or records state localities as suburbs, catchments, national parks or small creeks. Additional detail included such as north-west corner, street names or points up or down tracks or streams from landmarks, river crossings or confluences etc.	Upgraded to 2	10 km
5 - Specific B	As with Category 4 but with no additional detail given.	Label states suburbs, catchments, national parks or small creeks without additional detail.	5	10 km
6 - Detailed	General locality given by collector but with additional, more specific information. Latitude and longitude coordinates obtained from gazetteer, from 1:100000 maps or from other records.	Published paper gives a general locality description but also refers to a distance and direction from a known point or locality, or refers to junction of roads or mile pegs.	Upgraded to 5 or 3	50 km
7 - General	Only general locality information given.	Locality given as a town or large geographical feature such as an extensive range of hills, catchments or district. Specimen label may say, for example, "Near Walpole".	7	50 km
8 - Determinable	Even general locality absent Information given vague but can be upgraded.	Locality given as being between two towns. Location or feature unknown at this stage.	Upgraded to 7	NA
9 - Indeterminate	Illogical locality data. Labels illegible or spelt incorrectly. Information could refer to more than one locality or geographic scale far too broad.	Locality given as large river system or other large geological feature i.e. "Blackwood River" or "South-west Western Australia".	Specimen data omitted from analysis	NA

Note: This table is a modification of the one developed by the author and used in Horwitz et al. (1999).

Records were added periodically throughout the research both as a result of taxonomic separation of specimens and the acquisition of new material by the WAM or other studies. All new material received by the Crustacea section of the WAM up until the end of 2001 was included in the dataset. At the completion of microhabitat sample analysis, appropriate fields were added to the database and microhabitat data were added to the relevant records as necessary. A separate field in the database was created to make a distinction between material collected during this study, material collected by the WAM Urban Bushland Study (Harvey et al., 1997; How et al., 1996) and material that was part of the general WAM collection. Data were coded according to microhabitat type. The codes are given in Section 4.2 (Table 4.2)

2.8.1. ACQUISITION OF GIS DATA

GIS data were obtained for the purpose of mapping taxa distributions and constructing geographical grids. Maps were prepared using ArcView GIS 3.2 (ESRI, Redlands, California). Polygons, representing the framework of localities and LUs were plotted by the author. The IBRA GIS dataset (metadata and information on the assumptions of this dataset is given in Thackway and Cresswell, 1995) was used as a framework for distribution maps and for the calculation of area. The Vegetation Survey of Western Australia dataset (Unique Record ID ANZWA 1050000052) based on the vegetation mapping of Beard (1981b) provided the vegetation association data given in Appendix 2a. All GIS data were in decimal degrees and in Geodatum 94.

2.8.2. STATISTICAL ANALYSIS

Three software packages were used for the of data analysis. Most statistical analyses and graphs were produced in Microsoft Excel 2000 for Windows. Boxplots were produced in SPSS 11.0 for Windows and multivariate investigations and Multi Dimensional Scaling (MDS) ordination plots were performed in Primer V.5.2.1 for Windows. Some post-hoc changes to improve the clarity and presentation graphs were applied in Adobe Photoshop V 5 but no changes were made to the statistical nature of the data. Data transformations were undertaken where necessary and this is always indicated where the results are presented. MDS plots were created from similarity matrices derived from the measure of Normalised Euclidean Distances for environmental data and Bray-Curtis similarity matrices for the presence/absence data for the taxa. Statistical significance of correlation coefficients was determined using tables from Zar (1984).

2.9. GLOSSARY

Table 2.4 (repeated in Appendix 3) provides definitions of some terms used in this and the following chapters. The term "area" is generic and is used independently from those defined below. Other terms are developed and defined in subsequent chapters and are explained in full as they are developed.

Table 2.4.
Glossary of key terms used frequently throughout the thesis.

Term	Definition
Record	One or more specimens of a single taxon collected from a specific site on given date. Any differences in microhabitat, collection method and collector or WAM registration number necessitated a new record for a given taxon.
Region	The region is the geographical extent of the southwest of Western Australia is defined by the Darling Botanical District (DBD) (Beard, 1981b) as shown in Figure 1.3. This DND is largely synonymous with the Swan Coastal Plain, the Jarrah Forest and the Warren Bioregions as determined by Thackway and Cresswell (1995) and shown in Figure 1.4. Sampling in this study was conducted at sites only within the region.
Site	A place with specified latitude and longitude coordinates where specimens were collected as part of this or other study. Study sites sampled during this study are listed in Appendix 1a.
Locality	Southwestern Australia (the region) was divided into 120 localities. Localities represent approximately equal land areas of fifteen minutes latitude by fifteen minutes longitude. They were numbered consecutively in rows from the northwest to the southeast of the region and are shown in Figure 2.1(A). Localities were used a basis for determining sampling sites and for the purposes of biogeographical analysis. They coincide with Australian Topographic Survey 1:50 000 maps and the names of the sheets were used as locality names. Locality names, numbers and reference to maps are given in Table 2.1.
Supplementary Locality	For the purposes of analysis, the study area was extended by three supplementary localities. Locality 200 was added to incorporate records from Rottnest Islands since it fell outside the geographical limit of the localities defined above. Two other supplementary localities, the Stirling Range (201) and Mount Lesueur (202) are known to have high floristic diversity and occur just outside the region. They were included in the dataset since there was significant WAM material that warranted their inclusion. The boundaries of supplementary locality 201 were extended beyond the standard fifteen minutes of longitude to include all material from the Stirling Range National Park.
Landscape Unit (LU)	A composite area derived from a number of adjacent grouped localities. Landscape units (LUS) each encompass approximately the same amount of the study area. Some LUs coincide with areas shown on National Topographic 1:100 000 series maps while some are a combination of two maps. The relevant map names were used to name the LUs. LUs are used only to examine broader scale patterns of taxa richness and diversity within the region.
Zone	A biogeographical region delineated as a result of this study. Zones are identified in Chapter 6 and refined in Chapter 8. They were defined initially by grouping a number of adjacent localities with similar distributional and diversity characteristics. They were refined by delineating a major faunal break and areas of endemism.

2.10. DESCRIPTION OF THE STUDY AREA

To assist the reader in understanding what may be responsible for generating the patterns determined by this study, it is necessary to give a background to the region. The region has been defined from many standpoints. An extensive synthesis at the State level was provided by Gentilli (1979) and for the Swan Coastal Plain and the Perth region in particular by Seddon (1972) The region has been characterised as much by its hydrology and rainfall as it has by its vegetation The Darling Botanical District is notable because it is an area where drainage flows to the coast and not to ephemeral inland lakes. While many of the major rivers arise to the east of the Jarrah Forest Bioregion, the drainage within the region itself commences on a flat and ancient semi-arid inland plateau (Tray'.r et al , 1996) Rivers flow sluggishly toward the coast before passing through a zone where topography steepens and rainfall increases until they reach extensive coastal plains of the Swan Coastal Plain and the far south of the Warren Bioregion where they slow again and terminate in lagoon-like estuaries (Trayler et al , 1996).

In order to characterise the different parts of the study region, it is appropriate to draw upon probably the most succinct overview of the region to date. This was provided by Beard (1979) and an overview is presented in Table 2 5. It is based on the four botanical subdistricts, Drummond, Dale, Menzies and Warren, shown in Figure 1 3.

Following this description of south-western Australia, the next chapter provides a comprehensive documentation of the taxonomy of the terrestrial isopods found there.

Table 2.5
Characteristics of the Darling Botanical District based on those given by Beard (1979) with the last column has been added.

Subdistrict	Vegetation	Climate	Geology	Topography and Soils	Anthropogenic Influences
DRUMMOND	Mainly Banksia low woodland on leached sands with Melaleuca swamps where ill-drained; woodland of tuart, jarrah and marri on less leached soils	Warm Mediterranean, winter precipitation 600-1000 mm with 5-6 dry months per year	Mesozoic to recent sediments of the Perth Basin	A coastal plain. Low-lying often swampy, with sandhills, soils mainly recent or swamp deposits. Also dissected country rising to the duricrusted Dandaragan plateau on Mesozoics, mainly yellow sandy soils.	Heavily urbanised and or cleared for agriculture. Original vegetation occurs only in scattered remnants. A long history of aboriginal occupation. Recent increase in the frequency of fire
DALE	Jarrah forest on ironstones gravels and marri-wandoo woodlands on loamy soils	Warm Mediterranean, winter precipitation 600-1200 mm with 5-6 dry months per year	Archaean granite of the Yilgarn Block	Duricrusted plateau of the Yilgarn Block, surfaced with ironstone gravels, dissected toward the east with hard-setting loamy soils. Frequent outcropping of Granite with some significant Peaks such as Mount Cooke	Forest ecosystems heavily exploited for timber, selected areas cleared and rehabilitated for bauxite mining. Favourable soils cleared for agriculture. Some catchments dammed and managed for water production. Areas affected by diseases caused by Phytophthora cinnamomi. Aboriginal occupancy probably predominant in eastern areas.
MENZIES	Jarrah forest as for the Dale Subdistrict but with an understorey of differing composition becoming similar to the Warren Subdistrict	As for the Dale Subdistrict but conditions are slightly more humid	As for the Dale Subdistrict	As for the Dale Subdistrict	As for Dale subdistrict but more extensively cleared for agriculture and with some extensive plantations of Pinus spp.
WARREN	Tall forests of karri on deep loams, forests of jarrah marri on leached sands. Extensive paperbark (Melaleuca) and sedge swamps in valleys	Moderate Mediterranean, winter precipitation over 1000 mm with 3-4 dry months per year	Archaean granite and infolded metamorphic rocks of the Yilgarn Block	Dissected undulating country of small relief, hard setting loamy soils alternating with leached sand soils. Many coastally seasonally inundated areas.	More recent history of forestry but less extensive. Some clearing for agriculture. Aboriginal occupancy probably confined to coastal areas. Probable recent increase in the frequency of fire.

CHAPTER 3 - TAXA

3.1. INTRODUCTION

This chapter reviews the taxonomic status of terrestrial isopods in southwest Australia. It details those taxa that can be readily identified from the literature as it stands, and develops a mechanism for discriminating the remaining taxa to a level that is suitable for biogeographic study. It also reviews the historical and geographical foundation of knowledge of the region's terrestrial isopods to date. It shows that, prior to this study, the biogeography of the region's terrestrial isopods was incomplete and largely artefactual. The taxonomic literature also contains a significant amount of anecdotal information that I consider essential to an understanding of the nature of terrestrial isopod microhabitat utilisation in south-western Australia. For this reason I have endeavoured to capture and include this type of information in my review.

This Chapter can be divided broadly into two parts. The first part (Sections 3.1 to 3.4.) provides the background to the second part (Sections 3.5 to Section 3.20), which describes the taxa. As a background to both the taxonomic and biogeographic parts of this thesis, Section 3.2 comprises a taxonomic review. It does so comprehensively and chronologically, providing important detail of the methods and influences of some the collectors and authors. The following section (Section 3.3) outlines the methodology used to determine taxa. Following this, Section 3.4 provides a glossary to the terminology used in the chapter and comprehensive instructions for the interpretation of the remaining parts of the Chapter.

The second part begins with of a key (Section 3.5) to the identification of the terrestrial isopods of south-western Australia, an illustrated list of the characters (Section 3.6) used in their identification and an illustrated description of each of the taxa (Sections 3.7 - 3.17). The taxonomy of this chapter is underpinned by the desire to make it accessible and useful to non-specialist isopod or crustacean taxonomists as well as those familiar with terrestrial isopods. The key and its accompanying parts were designed so that field biologists, invertebrate ecologists or enthusiastic naturalists may identify the region's terrestrial isopods. In this light, its presentation differs from the types of keys usually found in taxonomic literature. However, the species descriptions and the determination of characters, follow the accepted taxonomic approach. The aims of this chapter are therefore to:

- review the taxonomy of the region's terrestrial isopods and understand some of the factors that have influenced it;
- establish a suite of reliable morphological characters to enable the determination of the taxa present;
- devise ways in which the taxa can be determined;
- describe, as comprehensively as possible, the taxa determined; and
- identify the taxa appropriate for a biogeographical study.

3.2. TAXONOMIC REVIEW

A list of the species of terrestrial isopods found in the region, compiled from the literature prior to the commencement of this study, is given in Table 3.1. Six of these have long been recognised as introduced species. Closer examination of the literature reveals that there have been three principal episodes of taxonomic activity, none of which are recent. The first descriptions were made by Budde-Lund (1912) in Latin and by Wahrberg (1922) in German. In the second episode, various descriptions were made locally by Nicholls (a zoology professor at the University of Western Australia) and his co-workers Miss Barnes and Miss Bowley. All their publications were in English and were, until recently, the most comprehensive. The third episode was the contribution made by Vandel (1973a) who undertook a review of the Australian Oniscidea. South-western Australia was well represented in his work, although only a few new taxa were described. His descriptions were brief and in French. The significance and background to each of these episodes is discussed below in Subsections 3.2.1, 3.2.2, and 3.2.3 respectively.

To avoid repetition, authorities for species are included or implied in the text only where they are not given in Table 3.1. Some specimens discussed in the following section are present in the Western Australian Museum (WAM). The appropriate WAM registration numbers (e.g. C31497) are given in parentheses. Subsections 3.2.4 and 3.2.5 summarise other relevant taxonomic work not covered by the three principal episodes.

Table 3.1.

List of species recorded from the southwest of Western Australia compiled from taxonomic literature and from published ecological studies where identifications have been made by recognised oniscidean taxonomists. Higher taxonomy follows Holdich et al. (1984).

Infraorder Ligiamorpha

Section Synocheta Legrand, 1946

Superfamily Styloniscoidea Vandel, 1952

Family Styloniscidae Vandel, 1952

1 Styloniscus australiensis australiensis Vandel, 1973
2 Styloniscus australiensis cavernicolus Vandel, 1973
3 Styloniscus otakensis Chilton, 1901
4 Styloniscus thomsoni Chilton, 1885
5 Styloniscus verrucosus Chilton, 1885

Section Crinocheta Legrand, 1946

Superfamily Oniscoidea Latreille, 1802

Family Halophilosciidae Verhoeff, 1908

6* Halophiloscia couchi Kinahan, 1858

Family Oniscidae Latreille, 1802

7 Hanoniscus monodi Bowley, 1935
8 Hanoniscus nichollsi Bowley, 1935
9 Hanoniscus tuberculatus Budde-Lund, 1912

Family Bathytropidae Vandel, 1952

10 Australoniscus springetti Vandel, 1973

Family Philosciidae Kinahan, 1857

11 Eurygastor sp. Vandel, 1973
12 Laevophiloscia brevicopore Wahrberg, 1922
13 Laevophiloscia dongarrensis Wahrberg, 1922
14 Laevophiloscia hamiltoni Vandel, 1973
15 Laevophiloscia karrakattensis Wahrberg, 1922
16 Laevophiloscia longicaudata Wahrberg, 1922
17 Laevophiloscia perlata Wahrberg, 1922
18 Laevophiloscia richardsae Vandel, 1973
19 Laevophiloscia subterranea Budde-Lund, 1912
20 Laevophiloscia yalgoonensis Wahrberg, 1922
21 Plymophiloscia sp.

Family Platyarthridae Verhoeff, 1949

22 Trichorhina australiensis Wahrberg, 1922

Family Scyphacidae Dana, 1852

23 Alloniscus nicobaricus Budde-Lund, 1885
24 Deto marina Chilton 1884
25 Haloniscus searlei Chilton, 1920

Superfamily Porcellionoidea Brandt & Ratzeburg, 1931

Family Actaeciidae Vandel, 1952

26 Actaecia pallida Nicholls and Barnes, 1926

Family Armadillidae Brandt & Ratzeburg, 1833

27 Armadillo bituberculatus Budde-Lund, 1912
28 Armadillo flavus Budde-Lund 1912
29 Armadillo integer Budde-Lund, 1912
30 Armadillo pygmaeus Budde-Lund, 1912
31 Pseudodiploexochus australiensis (Vandel, 1973)
32 Pseudolaureola wilsmorei (Nicholls and Barnes, 1926)
33 Buddelundia albomaculata Budde-Lund, 1912
34 Buddelundia cinerascens Budde-Lund, 1912
35 Buddelundia inaequalis Budde-Lund, 1912
36 Buddelundia nigripes Budde-Lund, 1912
37 Buddelundia nitidissima Budde-Lund, 1912
38 Buddelundia opaca Budde-Lund, 1912
39 Buddelundia rugifrons Budde-Lund, 1912

Family Armadillidiidae Brandt, 1833

40* Armadillidium vulgare Latreille, 1804

Family Porcellionidae Brandt & Ratzeburg, 1831

41* Porcellionides pruinosus (Brandt, 1833)
42* Porcellio laevis Latreille, 1804
43* Porcellio lamellatus Latreille, 1804
44* Porcellio scaber Latreille, 1804
45* Agabiformius lentus (Budde-Lund, 1885)

Family Trachelipidae? Strouhal, 1953

46 Undescribed species Bunn & Green, 1982

* Introduced species.

Note: Only taxa numbers are used subsequently in Table 3.2.

3.2.1. THE FAUNA OF THE SOUTH-WEST (1905-1922)

3.2.1.1. Budde-Lund's account of the Hamburg material

In 1905 the "Hamburg Expedition", led by Michaelsen and Hartmeyer, collected fauna throughout Western Australia. Oniscidea, presumably collected by Michaelsen, formed part of this collection and the leading Danish taxonomist Gustav Budde-Lund undertook to describe them. Unfortunately, Budde-Lund died in the autumn of 1911 whilst still working on the material[7]. His work was published posthumously, most of it constructed by Michaelsen from Budde-Lund's notes in Danish and partially completed Latin descriptions. Michaelsen noted that Budde-Lund had started systematically working through the material and had determined much of the material to genus. Nearly all of his work was on the Armadillidae, most which had been assigned to new, but as yet unnamed and undefined genera. Therefore, Michaelsen conveniently allocated them to the genus Armadillo Dumeril, 1816. Michaelsen noted that most of the specimens collected were either Philoscia sp. or Armadillo, with other taxa occurring infrequently and usually from a single locality. He stated clearly that, of the twenty-six occurrences of Armadillo, there were nineteen species. Although the collections of Philoscia exceeded all others, the genus received little attention from Budde-Lund. Michaelsen indicated that he had a jar containing many Philoscia and was unsure what to with it. He listed the localities from which they had been collected, but not the dates, and included them under the title of "Philoscia sp. (Species diversae?)". These will be discussed in the next sub-subsection.

The most significant observation by Budde-Lund was the partial description of the then sub-genus Buddelundia, posthumously named by Michaelsen. Budde-Lund (1912) described 16 species of Armadillo (Buddelundia) (7 of these were collected in the region) and 4 species of Armadillo (all from the region). Armadillo flavus and A. bituberculatus are the most comprehensively described but these cannot be determined from the descriptions and figures given. A. integer has a partial description and A. pygmaeus, except for figures of a maxilla and maxilliped of uncertain sex, has none at all. No species was completely figured.

Budde-Lund also provided incomplete descriptions for Philoscia subterranea from Yallingup Cave and Hanoniscus tuberculatus from Cannington and South Perth. A species of Deto from Rottnest Island and Alloniscus nicobaricus from Fremantle, were noted but no descriptions were given. The introduced species Porcellio scaber, P. laevis and Porcellionides pruinosus were widely collected and apparently already well established at town sites by 1905. They are recognised by Michaelsen as being non-endemic and the probable results of incidental transportation. The incomplete nature of

[7] Adverse reactions to the task in hand were also experienced by this author. Fortunately for him, these were not fatal.

all the descriptions and the absence of a diagnosis for the genus Hanoniscus are obvious limitations to the usability of this taxonomic work.

Michaelsen gave no microhabitat detail with any of the specimens described by Budde-Lund. However, there is something to be learned from an examination of the list of stations of the "Hamburg Expedition", found elsewhere among the papers describing the fauna of the southwest (Michaelsen & Hartmeyer, 1905 p.110-116). Figure 3.1, adapted from that given by Michaelsen, shows the location of terrestrial collecting stations within south-western Australia visited by the "Hamburg Expedition" in 1905. Site details, a chronological list of their visitation and the type localities of taxa described by Budde-Lund (1912) follow in Table 3.2. Site descriptions and any microhabitat information given were translated from the original German.

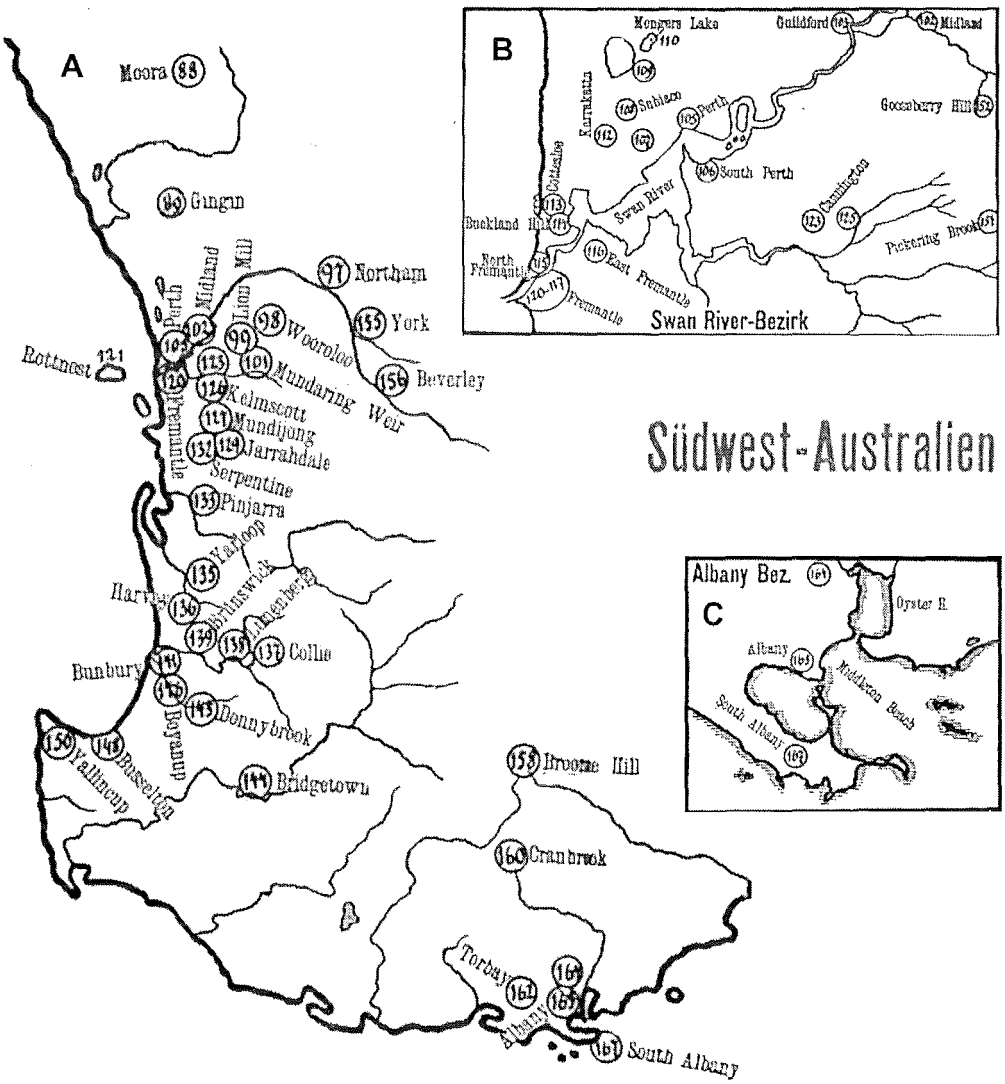


Figure 3.1 Sampling sites of the "Hamburg Expedition" visited in south-western Australia in 1905 (A). Inset are the stations in the Perth region (B) and the Albany region (C). Source: adapted from Michaelsen and Hartmeyer (1905).

Table 3 2

Chronological list of stations visited by the "Hamburg Expedition" in south-western Australia The taxa described by Budde-Lund (1912) are shown next to their appropnate station and date Species of Philoscia which were left undetermined by Budde-Lund are not included. The number code for each taxon corresponds to those in Table 3 1 and the number of specimens collected is given in parentheses

Station (number)	D/M/1905	Site Description	Taxa
Fremantle Obelisk Hill (S119)	5/5	coastal limestone hill with loose stones	
Fr[illegible]antle (S120)	7/5	house and garden	
Buc[illegible]and Hill (S114)	7/5	coastal bushes and gardens	
Fremantle (S118)	8/5	churchyard	
Lake Monger (S110)	9/5	permanent freshwater	
North Fremantle (S115)	10/5	coastal dunes and bushes	
South Perth (S106)	10/5	brackish water on flatland west of the Darling Ranges	9 (3)
Lake Monger (S110)	13/5	permanent freshwater	
North Fremantle (S115)	13/5	coastal dunes and bushes	
Lake Monger (S110)	16/5	permanent freshwater	
Subiaco North (S109)	16/5	coastal forest	37 (1)
Cottesloe (S113)	18/5	coastal dune scrub and bushes	
Guildford (S103)	19	flat land west of the Darling Ranges with bushes occasional tall trees and farmland	39 (1), 37 (1), 30 (6)
Fremantle Obelisk Hill (S119)	20/5	coastal limestone hill with loose stones	35 (6)
Buckland Hill (S114)	21/5	coastal bushes and gardens	
Lion Mill (Mt Helena) (S[illegible]	22/5	hilly land with tall forest on the western slope of the Darling Ranges	
Fremantle Obelisk Hill (S11[illegible])	24/5	coastal limestone hill with loose stones	
Karrakatta (S112)	28/5	tall dry coastal forest	
Wooroloo (S98)	29/5	hilly land with tall trees on the eastern slope of the Darling Ranges	37 (2)
Gooseberry Hill (S[illegible]52)	31/5	hilly land with bushes and with creeks in the Darling Ranges	40 (8)
Buckland Hill (S114)	1/6	coastal bushes and gardens	
North Fremantle (S115)	24/6	coastal dunes and bushes	

Station (number)	D/M/1905	Site Description	Taxa
Fremantle (S118)	25/6	churchyard	
Lion Mill (Mt Helena) (S99)	26/6*	hilly land with tall forest on the western slope of the Darling Ranges	37 (1)
East Fremantle Rec Ground (S116)	27/6	coastal land with tall forest	
Cannington (S123)	28/6	swamp land with ponds on flat land west of the Darling Ranges	9 (7)
East Fremantle Rec Ground (S116)	19/7	coastal land with tall forest	39 (5)
Lion Mill (Mt Helena) (S99)	20/7	hilly land with tall forest on the western slope of the Darling Ranges	
Pickering Brook (S154)	22/7	tall forest with some swamps in the Darling Ranges	
Fremantle (S117)	23/7	coastal limestone hill near churchyard	
Bunbury (S142)	24-25/7	coastal dune and bushes	36 (many) 8 (8)
Harvey (S136)	27/7	high forest with farmland on flatland west of the Darling Ranges	37 (1)
Donnybrook (S145)	28-29/7	tall forest in the Darling Ranges	37 (1)
Bridgetown (S144)	30-31/7	tall forest in the Darling Ranges	
Boyanup (S146)	1-3/8	high forest and farmland on flat land west of the Darling Ranges	37 (3)
Moora (S88)	8/8	bushland	7 (8)
Lion Mill (Mt Helena) (S99)	9/8	hilly land with tall forest on the western slope of the Darling Ranges	
Mundaring Weir (S101)	9/8	hilly land with bushes on the western slope of the Darling Ranges	37 (1) 28 (7)
York (S155)	11/8	stony hills with bushes and farmland	7 (1)
Albany (S165)	13-22/8	coastal hills with stones and bushes	
South Albany (S167)	16/8	tall forest and exposed stony hills	
Kings River NE Albany (S164)	17/8	tall forest with partial swamps on flat land south of the Stirling Ranges	
Torr[illegible] (S162)	19/8	tall forest with partial swamps on flat land south of the Stirling Ranges	26 (10), 27 (2)
Crawbrook (S160)	23/8	sparse (thin) tall forest west of the Stirling Range	
Broome Hill (S158)	24-25/8	tall forest	33 (5)
Collie (S137)	26/8	tall forest with swampy areas	
Lion Mill (Mt Helena) (S99)	27/8	hilly land with tall forest on the western slope of the Darling Ranges	
Guildford (S103)	28/8	flat land west of the Darling Ranges with bushes occasional tall trees and farmland	

Station (number)	D/M/1905	Site Description	Taxa
East Fremantle Rec Ground (S116)	29/8	coastal land with tall forest	
North Fremantle (S115)	30/8	coastal dunes and bushes	23 (4)
North Fremantle (S115)	2/9	coastal dunes and bushes	
Rottnest Island (S121)	6-13/9	dunes with dense bushes limestone rocks)	24 (many), 34 (8)
Buckland Hill (S114)	17/9	coastal bushes and gardens	
Jarrahdale (S129)	19-20/9	high forest on hills on the western slopes of the Darling Ranges	
Pinjarra (S133)	23/9	mainly under stones and logs on flatland west of the Darling Ranges	
Fremantle (S120)	25/9	house and garden	
Perth (S105)	26/9	brackish water on flatland west of the Darling Ranges	
Yallingup Cave (S150)	5/10	coastal limestone cave about 30 m deep with penetrating tree roots	19 (1 ,)
Yallingup (S151)	5/10	coastal swampland and bushes	
Brunswick (S139)	7/10	sparse (thin) tall forest in the Darling Ranges	39 (1)
Lake Monger (S110)	10/10	permanent freshwater	
Fremantle (S120)	10/10	house and garden	
Albany (S165)	10/10	coastal hills with stones and bushes	
Lion Mill (Mt Helena) (S99)	11/10	hilly land with tall forest on the western slope of the Darling Ranges	
Fremantle (S118)	13/10	churchyard	
South Perth (S106)	14/10	brackish water on flatland west of the Darling Ranges	
Fremantle Obelisk Hill (S119)	15/10	coastal limestone hill with loose stones	
North Fremantle (S115)	15/10	coastal dunes and bushes	
Fremantle Obelisk Hill (S119)	17/10	coastal limestone hill with loose stones	

* This locality has been added at this date because a specimen was recorded from it on that date Therefore, the list does not correspond exactly with the data given by Michaelsen

The most striking feature of Figure 3 1 is the lack of stations in what is now known as the Warren Bioregion (see Figure 1 4) Most stations are clustered around settlements or are en route between major centres The likelihood is that most type localities as described by Michaelsen (Table 3 2) have been lost to urbanisation or that the habitat they provided exists only as small remnants within highly modified landscapes

There were only eight of the fifty-six terrestrial (non wetland) stations at which Oniscidea were not recorded. These were Gingin (S89), Mundijong (S127), Serpentine (S131), Yarloop (S135), Lunenberg (S138), South Bunbury (S141), Busselton (S148) and Beverley (S156) Despite the fact that stations were often sampled more than once (e g stations around Fremantle and Lion Mill) there are no records of any species determined by Buddle-Lund being collected twice from a single station Michaelsen only lists the localities, and not the dates, for those taxa left undetermined by Budde-Lund (non-armadillids) so it is not possible to determine whether these were collected more than once at a single locality The Philosciidae were later investigated by Wahrberg (1922) but he gave no dates either

The genus Philoscia (as indicated by Michaelsen) was the most abundant and was reported from all sites except Perth (S105), Subiaco North (S108), Buckland Hill (S114), Fremantle (S117, S118, S120), Brunswick (S139), Torbay (S162) and Albany (S164) Budde-Lund, however, described only one Philosciid, Laevophiloscia subterranea from a single female specimen from Yallingup cave Given its highly specific locality this species should be relatively easy to recollect. The most common introduced species, Porcellionides pruinosus, was found with many examples at Fremantle and surrounding sites, at Perth (S105), Bunbury (S142), Donnybrook (S145), York (S155) and at Mundaring Weir (S101) Porcellio laevis was collected from Fremantle and surrounding sites, Perth (S105), Bunbury (S142), Donnybrook (S145), York (S155) and Albany (S164) Albany was the only station from which the now common Porcellio scaber was collected It is interesting to note that Armadillidium vulgare, also now a common urban species, was not collected at all.

There were some understandable inconsistencies in Michaelsen's reconstruction of Budde-Lund's work Five specimens of B rugifrons (39) listed as being collected from East Fremantle are given the station number of S110 This number represents Monger's Lake at which only Philosciidae were collected. However, the date given (19 VII 05) is consistent with East Fremantle This is important since one of these specimens is likely to be one of those figured by Budde-Lund East Fremantle is the only one of the three stations where more than one specimen of B rugifrons was collected The single specimen from Brunswick is present in WAM material (C31768), is undissected and therefore is very unlikely to be Budde-Lund's holotype

There are two inconsistencies in the specimens of B nitidissima (37) listed The single specimen from Lion Mill is given a date of 26 VI 05 As stated in the notes accompanying Table 3 2, this site does correspond with this date in the descriptions

given by Michaelsen It may be erroneous since it appears chronologically between two sampling events in Fremantle Likewise, the specimen from Mundaring Weir is recorded as being collected on 4 VIII. 05 The correct date given for Mundaring Weir is 09 VIII 05 so this may be trivial error More importantly, Budde-Lund does not give the locality for the specimen he figured As he figured both a male and a female it is likely that they are from Wooroloo (2 specimens) or Boyanup (3 specimens) because these are the only stations from which multiple specimens were collected That is unless he figured a male and female from different localities. This would be extremely problematic given the widespread distribution of this species and its similarity to a number of other Buddelundia species The acquisition of Budde-Lund's type material from the Museums in Hamburg and Stockholm, should it be available, is the only way to settle this matter

A single specimen of Angara n sp. (46) was recorded from York (S155) Although the date is apparently correct, the station number given (S150) was that of Yallingup A similar error occurred with Hanoniscus tuberculatus which was also collected from York but given the station number of Yarloop (S135). This was probably a simple typographical error

Of Budde-Lund's determinations, the WAM holds the following type material Armadillo flavus (C374, pleon missing), A integer (C393, head and first pereonal segment missing), Buddelundia albomaculata (C394), B cinerascens (C375, head missing), B inaequalis (C377, complete male specimen); B. nigripes (C396); and, B opaca (C379) The specimen of B. rugifrons from Brunswick (31768) is not recorded as type material Specimens of Alloniscus nicobaricus (C368) collected from North Fremantle are also present In most cases, it is not clear whether a male or female has been figured by Budde-Lund. Fortunately, aside from the two species of Buddelundia already mentioned, all other species are described from a single type locality This makes the necessary task of redescribing these species a little easier

3.2.1.2 Wahrberg's account of the Hamburg material

The problem of Michaelsen's jar of Philosciids and other accumulated material in the Museums of Stockholm and Hamburg was tackled by Ragnar Wahrberg and published in German in 1922. This included a review of the Hamburg expedition material and descriptions of material collected in eastern Australia by the Swedish collector, Dr Eric Mjoberg A breakdown of the south-western Australian material described or determined by Wahrberg is as follows

Michaelsen (p.41) listed 30 stations from which Philoscia spp were collected Wahrberg provided details of taxa for only 17 of these stations Consequently, the Philosciid material collected from Broome Hill (S158), Cottesloe (S113), Cranbrook (S160) Donnybrook (S145), East Fremantle Rec Ground (S116), Fremantle Obelisk Hill (S119), Harvey (S136), Lake Monger (S110), Moora (S88), Pickering Brook (S154), Pinjarra (S133), South Albany (S167) and York (S155) remained undetermined

A subgenus, Laevophiloscia, was instituted by Wahrberg to accommodate these Philosciids His diagnosis (Wahrberg p 101-2) is based entirely upon characters of the mouthparts Two species described by Wahrberg are from type localities outside the present study region, Laevophiloscia dongarrensis from Dongarra and L yalgoonensis from Yalgoo and Day Dawn (near Lake Austin) respectively Both included descriptions of male specimens and figures of male pleopods L perlata was described from material collected from Cannington, Bunbury, Guildford, Collie, Rottnest, Lion Mill, Albany, Mundaring Weir, Boyanup, Bridgetown, North Fremantle, South Perth, and Karrakatta in the study region and, curiously, Denham on Point Peron, Shark Bay Figures included both male and female pleopods but there is no indication by Wahrberg as to where the figured specimens came from The situation is less satisfactory still with three other species described by Wahrberg L longicaudata was described from only two females, one from Northampton and one from Bridgetown (two very distant and remarkably different localities), only the pleopods are figured and it is not stated which specimen this was A similar situation exists for L brevicorpore, only a single female specimen was described from Jarrahdale Unlike L longicaudata and L brevicorpore, L karrakattensis was described from two male specimens from Karrakatta and some of the male pleopods were figured There are obvious problems associated with describing only males from one locality and only females from another Since males are now nearly always required for the complete description and consequent identification of Oniscidea, it is not possible to determine confidently any Laevophiloscia described by Wahrberg without reference to type material. Preliminary determinations are possible as has been made by others (e g Bunn & Green, 1982) but a comprehensive review, nomination of a type species, and redescription of all species is needed

Aside from Laevophiloscia, Wahrberg also described Trichorhina australiensis The description is comprehensive and, although only male pleopods were figured, both male and female characters are described It seems as if Wahrberg examined little of the Armadillidae described by Budde-Lund, no mention of the four species assigned to Armadillo by Michaelsen was made and, of the Buddelundia, only B cinerascens was redescribed and some characters of B nitidissima were compared to a new species described from Adelaide Wahrberg considered Buddelundia a genus in its own right and gave a clear diagnosis based on the unique arrangement on the pleopods Except for the inclusion of three new species (all from eastern Australia), he reproduced Budde-Lund's key to the species Wahrberg attributed the species of Deto found at Rottnest to Deto marina, and, of the three species of Hanoniscus partially determined but not described by Budde-Lund, two were attributed to New Zealand species and a third was not mentioned These will be discussed in the next section

Wahrberg examined five female specimens of Trichoniscus He attributed these to the New Zealand species T otakensis & T thomsoni and to T verrucosus from the Crozet Islands Green (1971) has since separated similar Tasmanian species from those found in New Zealand, suggesting that Western Australian forms are also likely to be different

T. verrucosus was found at Lion Mill (now Mt. Helena), T. otakensis at Bridgetown and Yallingup and T. thomsoni at Jarrahdale. It is remarkable that such extensive collecting produced only five specimens of Trichoniscus (now Styloniscus). This perhaps reflects the fact that the wettest part of the region was not sampled. Nevertheless, the Styloniscidae are a conspicuous part the fauna in moist parts of the jarrah forest. The fact that so few were recorded is suggests that site selection may have been a function of forest accessibility and favoured untypical forest conditions.

During the same years that Budde-Lund and Wahrberg were working on Western Australian material, the Professor of Biology at Canterbury College in New Zealand, Charles Chilton, was working on material from both eastern Australia and New Zealand. While he did not describe material from Western Australia, some of the species are either found here, such as Haloniscus searlei described from salt lakes in Victoria (Chilton, 1920) and the sub-Antarctic genus Deto (Chilton, 1915a) represented by Deto marina, or are closely related to local species. The most notable close relative of south-western Australian species is perhaps Notoniscus tasmanicus (Chilton, 1915b).

3.2.2. SWAMPS AND HOLIDAYS (1926-1935)

Shortly after Wahrberg's publication in 1922, local worker Nicholls and his colleagues described four species of Western Australian terrestrial isopods. Two of these, Haloniscus stephensi (Nicholls & Barnes, 1926) & Schismadillo spencerii (Barnes, 1934), were found well outside the region whilst Actaecia pallida and Cubaris wilsmorei, both described by Nicholls and Barnes (1926b), were from the study region.

The first of these species, C. wilsmorei, was collected from Nornalup in the far south of the region. Nicholls, along with his colleagues and students, were obviously frequent visitors to this area. The data from much of their WAM material reveals a number of annual visits coinciding with holiday periods during 1924-1925 and again in the early 1930s. Nicholls' descriptions are characterised by an understanding of the importance of microhabitat recognition in the process of collecting specimens. This awareness, combined with the thorough descriptions he and his co-workers provided, make them the most useful contribution to the knowledge of the region's Oniscidea. In remarking on the collection of C. wilsmorei on his first trip to Nornalup with camp companion Prof. N. T. Wilsmore he noted: "A few specimens ... were found hiding under moss growing upon the shaded side of a giant Karri" (Nicholls & Barnes, 1926b, p.149). These specimens were collected from Nornalup in November 1925. The circumstances surrounding this trip are given by Nicholls who said: "Nearly two years later ... when a field instruction class was held at Nornalup they [specimens of C. wilsmorei] were obtained in larger numbers. The greater part were taken along the bank of the Frankland River under large logs in the immediate wake of an extensive and still burning bush fire, but they were nowhere plentiful" (Nicholls & Barnes 1926b, p.149).

A single jar with many specimens of this species collected at Nornalup on the 21. XII. 25 from under logs and determined by H. M Barnes are present in the WAM collection (C31497). These are clearly part of the type series and, since no type material is listed as being held by the WAM (see Jones, 1986), these should be nominated as co-type material. In describing C. wilsmorei, Nicholls was at pains to point out the difficulty in placing his new species within an existing genus He noted resemblances to the South American Diploexochus echinatus Brandt, 1833 and Cubaris longispinis Richardson, 1912 and the South African Akermania spinosa Collinge, 1919 In correspondence with Nicholls, this matter was dealt with by Vandel (1973a) and will be discussed again later

Nicholls' interest in both marine and freshwater amphipods and isopods (this was much the greater part of his work) suggests that much of his material came by way of incidental collection Bowley, a latter co-worker of Nicholls, began a review (Bowley, 1935 p 45) of the hygrophilic Hanoniscus by informing the reader that "during a number of years there has been accumulating in the collection of the Biology Department at the University of Western Australia a large amount of the Terrestrial Isopods. Recently, at the suggestion of Professor G. E. Nicholls ... an examination of this material was undertaken". The second of the region's Oniscidea described by Nicholls and Barnes was the littoral Actaecia pallida which was easily accommodated by Actaecia Dana 1853 and with affinities to A. euchroa an A ophensis, recently described by Chilton (1910), from beaches in New Zealand. Again, the clarity with which Nicholls described the habitat of the species makes the task of collecting easier. "This species has been taken on the beach at Leighton and Cottesloe from tightly rolled balls of Cymodoce stalks washed up on to the shore Probably it enters these from the sand at or near tide mark They may be submerged at times. Their colour harmonizes wonderfully with the white sand of the sea shore and this, with their power of curling into a ball, makes them difficult to distinguish" (Nicholls and Barnes 1926b p 158).

The accumulating material dealt with by Bowley was published in 1935 in the form of a revision of the south-western forms of the genus Hanoniscus. Three species of Budde-Lund's sub-genus Hanoniscus were described. Wahrberg had examined "Hamburg Expedition" material from Perth and Dongarra and thought the Western Australian forms to be conspecific with the Phalloniscus kenepurensis (Chilton 1901) and P. punctatus (Thomson 1879) respectively. This is confusing because Budde-Lund (Michaelsen) did not record Hanoniscus from either of these stations. Bowley found it necessary to re-examine all the material determined by both Budde-Lund and Wahrberg and concluded that Western Australian forms differed substantially from New Zealand forms in both characters of the mouthparts (not examined in detail by Wahrberg) and the scale-setae, and therefore constituted at least a new subgenus. Bowley (1935) provided a clear illustration of the characters separating Western Australian forms to which Budde-Lund's Hanoniscus had prior claim The type species H tuberculatus was reported by Budde-Lund from South Perth, Cannington and York. Bowley examined the specimens from Cannington and recollected material from South Perth. The bulk of the material

examined came from Pelican Point, a site very close to the University where Bowley worked, and there is a good representation of it in the WAM. The swampy nature of the habitat of this species was noted by Bowley (1935 p 58) "specimens were collected from under decaying sacks on the edge of a swamp which exists on a peninsular projecting into the Swan River". This area is now a highly modified foreshore environment, as are the swamps in South Perth.

The specimen examined by Budde-Lund from York, although labelled "Hanoniscus tuberculatus B.-L. Type!" (Bowley 1935 p. 47) was undissected and did not correspond with H. tuberculatus as figured by Budde-Lund. This proved to be the same species that was collected by the "Hamburg Expedition" from Moora and Dongarra[8] Bowley named this species H. monodi characterized by the shape of the telson, the presence of a crest along the hind margin of the head and the coarsely granulate nature of the pereon. The nomenclature of H. tuberculatus and H. monodi is confusing since H. monodi is more obviously tuberculate than H. tuberculatus The specimens from Dongarra could have come from swampland since one of three stations visited by the "Hamburg Expedition" was brackish swampland at the estuary of the Irwin River. Specimens collected by Bowley from Wooroloo were from "under stones on the banks of a creek where the soil was permanently damp [and] .. from under the bark of trees" Bowley (1935 p 63).

A third species of Hanoniscus, H. nichollsi, was described from specimens collected by Nicholls at Nornalup at the same time as C. wilsmorei. Bowley collected a few further specimens in 1933 "from under fallen karri logs found on the hill slopes of Walpole inlet" (Bowley, 1935 p 60). The specimens from Bunbury (coastal dunes and bushes) collected by the "Hamburg Expedition" were included in this species This species, occurring much farther south than its sisters, does not seem to be associated with swamps.

3.2.3 CAVES, FIRE AND VANDEL (1970'S)

Vandel (1955) examined southern hemisphere Trichoniscus and recognised a new family and genera. The genus Australian representatives of the genus Trichoniscus became Styloniscus and a generic diagnosis was given Western Australian specimens of Trichoniscus determined by Wahrberg, although not examined, were included in the new genus Styloniscus Shortly afterwards, Green (1961) studied Tasmanian Oniscidea and separated Tasmanian species of Styloniscus from those in New Zealand

Other than this minor development, the Western Australian Oniscidea did not feature in the literature again until the 1970s. Vandel (1973a, p.1) cites Nicholls as one of the important correspondences in undertaking his revision of the Australian Oniscidea His review included the description of five new species from the region. Four of these, Styloniscus australiensis, Laevophiloscia hamiltoni and richardsae and Hybodillo

[8] These were collected by Michaelsen in 1905 but not mentioned by him They were examined by Wahrberg and Bowley

australiensis are from cave material donated principally by Mrs J. Lowry. The fifth and perhaps most interesting, since it is probably one the most restricted and possibly ancient species yet known from the study area, is Australoniscus springetti collected by Dr. J. Springett. Vandel made an important error involving the type locality of this species and it merits a full explanation. Vandel (1973a, p. 43) gave the type locality as "Hamelin Pool, ca 600 miles north of Perth. Specimens collected from undersurface of algal concentrations near edge of the sea. Water in the habitats was less salty than the sea water which had a scum of salt on the surface. Rich loam with deep litter over granite. Dominant tree: Eucalyptus diversicolor – 7 IV. 1971." Clearly there is an error here since the dominant tree (Karri) grows only in the far south of Western Australia and certainly not 600 km north of Perth. The label with the type specimen says "Site 36 - Porongurups". Specimens of A. springetti collected by Springett on 9. IV. 1971 from the Porongurup Range were also examined during the course of this study. Since the vegetation description fits the Porongurups, there can be no doubt that Vandel has assigned the type locality incorrectly. Hamelin Pool was Springett's Site 37 and the Porongurups Site 36, it likely that the station numbers have been incorrectly transcribed at some point resulting in the wrong locality being recorded.

In describing S. australiensis, Vandel (1973a) suggested that the species was conspecific with material determined as Trichoniscus otakensis by Wahrberg (1922, p.76) and gave the localities from which Wahrberg reported T. otakensis as part of his new species distribution. Vandel describes the species as "...parfaitement lisses" (p. 20) meaning totally smooth. He also stated that the species was reminiscent of T. pusillus another smooth species (see Sutton, 1972, Plate 4) which is common throughout Europe. The description of T. otakensis by Chilton (1901, p.117) includes the following statement: "whole dorsal surface thickly covered with irregular, densely crowded tubercles". Clearly, Vandel was in error in synonymising T. otakensis with S. australiensis. The description of S. australiensis was brief and Vandel did not figure the whole animal. Of the species of Trichoniscus described by Chilton (1901), S. australiensis most closely resembles T. phormanius, a species not mentioned by Wahrberg. To make matters more confusing, Vandel (1973a, p.21) later indicated that some of the characters in which the species differed from the subspecific form (S. australiensis cavernicolus) were that it had four rows of "granulations" on pereonite 1 and three rows on the others.

Along with Vandel's (1973a) description of L. hamiltoni and L. richardsae was a redescription of L. valgoonensis, described originally by Wahrberg. This included an assessment of the number and location of noduli laterales, an increasingly important character at the generic level. However, Taiti who has examined specimens of L. valgoonensis from the type locality has found Vandel's account of the noduli laterales to be incorrect (S. Taiti, pers. comm. 30/08/02) and considers that a new generic diagnosis is necessary. Vandel also suggested that Laevophiloscia subterranea from Yallingup cave described by Budde-Lund may be con-specific with L. hamiltoni which was found in caves of the Augusta and Jurien Bay areas. The single specimen of Angara n. sp.

indicated by Budde-Lund was later identified by Vandel as the introduced species Agabiformius lentus.

A great deal of terrestrial isopod material was collected by Dr. J. Springett in the early 1970s. Some of it was generated by studies of soil and litter fauna in both jarrah (Springett, 1976; 1979) and karri forest (Springett, 1976) on the impact of fire upon terrestrial invertebrate communities. In unpublished papers found in the WAM, Springett indicated that much of the material she collected was sent to Vandel but arrived too late for inclusion in his review of the Australian Oniscidae. Nevertheless, a notable inclusion of Springett's material by Vandel is some specimens of his genus Eurygastor. Vandel created this genus, based on the character of extended pereonal epimera (pleura) and mouthparts, for material from New South Wales and Victoria. Green (1990) later designated E. montanus as the type species since the principal defining character, the extended pleura, was most obvious in this species. Material (C11018) from the northern jarrah forest, collected by Springett, with mouthparts dissected and determined by Vandel is present in the WAM collection. The pleura of the Western Australian specimens is less developed than those of E. montanus, as figured by Vandel (1973a), but distinctly more so than it is in Laevophiloscia.

Vandel divided the Armadillidae into a series of eight subfamilies, four of which were established in lit. and four of which were new. These were defined by a range of characters but, in particular, the nature of the lobes on the ventral surface of the pereonal epimera, especially those of the first pereonal epimeron. At the time, three of these subfamilies were represented in south-western Australia. Vandel considered the subfamily Buddelundiinae Verhoeff, represented by the single genus Buddelundia, to be a sub-branch of the Armadillidae due to the unique arrangement of the pleopods. This was, according to Vandel, an adaptation to desert climates. These divisions are doubtful however, since the African Armadillidae were not included in their establishment (Schmalfuss & Ferrara, 1983). Consequently they are not used in this work.

Of particular note is Vandel's treatment of A. flavus. He mentions the species twice; firstly, in the sub family Armadillinae in the section entitled "Espèces décrite sous le nom d'Armadillo" (p. 130) in which he says that the species is most probably a species of Cubaris and, secondly, in the Buddelundia (p. 147) where he records the species as B. flava occurring in the Great Victorian Desert. It can be seen clearly in Budde-Lund (1912, taf. 1, fig. 60) that the arrangement of the pleopods excludes this species from Buddelundia. Vandel also recorded B. nitidissima from a cave entrance near Augusta, this determination is also doubtful since this is well outside the known distribution of this xeric species and is most probably B. nigripes, a similar species common in that area.

3.2.4. POST VANDEL DEVELOPMENTS

Bunn and Green (1982) published a list of the Oniscidea of Rottnest Island (Supplementary Locality 200 shown in Figure 2.1). Eleven taxa were identified and

useful microhabitat detail and notes on seasonal activity were given. One potentially new taxon (Platyarthridae sp. nov.?) was recognised but not described. Three of the eleven species were introduced palearctic species and three were littoral or secondarily aquatic (Haloniscus searlei) with wide distributions. The remaining four species L. perlata, L. karrakattensis, T. australiensis and B. cinerascens were Western Australian endemics.

Taiti and Ferrara (1979) examined the genus Pseudodiploexochus from material collected from southern and central Afric They provided a generic diagnosis and pointed out that Vandel's description of P. australiensis showed characters of the first pereonal segment and the uropod t correspond with Herold's original description of the genus and included it in Pseu exochus. More recently, Lewis (1998a) described a second species of Pseudodiploexochus, P. pacificus, from Lord Howe Island. This paper also included a nomination of a type species. P. pacificus has a similar though not identical, arrangement of bumps on the pereonites to species examined from Western Australia, far more than it does to African species described by Taiti and Ferrara (1979; 1987). There is a strong homogeneity within the group (Lewis, 1998a) and individuals are very small (< 3 mm). Ferrara and Taiti (1983) suggest that the arrangement of bosses of tubercles on the dorsal surface is the most useful character for determining species. In this case, the description of P. australiensis given by Vandel (1973a) is inadequate for its reliable determination. This species needs to be redescribed before further descriptions of potential new species of this genus from the region can be made.

Aside from the distinctive Buddelundia, the history of many of the genera of Australian Armadillidae is extremely convoluted and comparative analysis of the Australian, African and Indo-Pacific material is necessary for the confident determination of genera. The examination of type material (e.g. Lillemets & Wilson, 2002) and subsequent descriptions are necessary to allow a confident generic diagnosis for many species. It is neither possible, nor practical to undertake this work here. However, it is desirable to recognise generic affinities of the region's Armadillidae and to assign taxa into "holding centres" (sensu Green 1974, p. 245) while genera await revision. To this end, the following paragraphs give a taxonomic background to those genera representing "holding centres" to which I have assigned the south-western Australian armadillids.

3.2.4.1. Armadillidae "holding centres"

Barnard (1932) suggested that C. wilsmorei[9] rightly belonged the genus Akermania as had been first suggested by Nicholls. There was a strong similarity between this species and material he was examining from southern Africa. Nicholls agreed with this diagnosis and on March 21, 1947 wrote to Vandel to "... point out that the specimen recorded as Cubaris wilsmorei is incorrectly named. ... since our paper was published, Barnard in

[9] One of the most remarkable of the region's Oniscidea and the only armadillid to be described in English

South Africa has called attention to details of structure distinguishing Akermania which were not provided by Collinge and by any chance having occasion to correct errors in nomenclature I should be pleased if you would set this matter straight." (Vandel, 1973a p. 158). This, Vandel attempted to do.

Barnard (1960) later went to on establish a new genus Laureola to incorporate three of Collinge's species of Akermania and three new species from southern Africa. The diagnosis he provided was incomplete and contained a mistake relating to the absence of a "flange or tooth" on the ventral surface of pereonal epimeron 1 and 2 which were in fact present (Kwon, Ferrara and Taiti, 1992). Vandel, when describing two new species from under logs in rainforest of eastern Australia, provided a new definition of Laureola and instituted the new genus Pralaureola to which he considered the two new species belonged. As Kwon et al. (1992, p.645) succinctly point out: "curiously all Barnard's species fit Vandel's definition of Pralaureloa while none can be placed in Laureola sensu Vandel, 1973". The matter was dealt with by Schmalfuss and Ferrara (1983) who synonymized Pralaureola Vandel, 1973 with Laureola Barnard, 1960 and instituted the new genus Pseudolaureola for Laureola sensu Vandel. They included three species P. wilsmorei, P. atlantica (Vandel, 1977) from St. Helena and P. hystrix (Barnard, 1958) from Madagascar. Kwon et al. (1992) designated the type species as P. atlantica. Therefore, until it is possible to make a comparative analysis with P atlantica, the Western Australian species is assigned to Pseudolaureola sensu Kwon, Ferrara & Taiti (1992).

A new species, Pseudolaureola deharvengi Dalens, 1998 has recently been described from New Caledonia and a revised diagnosis of the genus was given. Translated from the original French it reads: "Pereonal epimera, with the exception of epimeron 1, and sometimes the pleonal epimera, extended and pointed giving them a foliate appearance. Exopodites of the first male pleopod very reduced or absent. Exopodite of the uropod absent or very small if present" (Dalens, 1988, p. 94). In the case of Western Australian species, both the first male pleopod exopodite and the uropod exopodite are absent. Despite a general agreement with characters, P. wilsmorei looks remarkably different to P. deharvengi.

The genus Cubaris has been redefined by Green (1961) and Vandel (1973a). Vandel suggested that the genus represents a primitive type of armadillid in which the conglobating mechanism is slightly different. He thought the genus important because of the number of species it contains (>100, Lillemets & Wilson, 2002). The genus is widely distributed, encompassing much of the southern hemisphere. Cubarids from Lord Howe Island were described by Lewis (1998a) who noted that Schmalfuss (1983 p. 389, cited in Lewis, p. 757) considers Cubaris "as it has been defined in the past, [to be] a heterogeneous group defined by symplesiomorphic characters". Whilst concurring with this view, Lewis used the taxon in its current conception, but no diagnosis or reference to a recent diagnosis was given. Indeed, one of the species described by her (C.

granulatus) was given a name that had already been used for a species from India[10]. Schmalfuss and Ferrara (1983) suggested that a new diagnosis was not necessary and the most comprehensive treatment of the genus was that of Green (1961). Species assigned here are therefore sensu Green (1961, p. 329). All pertinent characters are described in subsection 3.17.5. However, the most significant character is the small endolobes on pereonal segment 1. The lobes are well separated from the lateral margin of the pereonal epimera and this means that there is no schisma of the pereonal epimeron. The lobes abut the second epimera rather than interlocking. This, presumably, is what Vandel (1973a) meant when noting differences in the method of conglobation. All other genera of Armadillidae from the region, including Buddelundia, have pereonal 1 endolobes producing a schisma.

The genus Spherillo has a protracted and confusing history. It was established by Dana (1852) and included four species without designation of a type species. The genus was reviewed and redefined by Green (1961) and her account of it runs to some six pages. It is not necessary to repeat this here. The matter was clarified further by Green, Ferrara & Taiti (1990) who concluded that the only way for unequivocally redefining the genus is to examine the four species described by Dana in 1853 and to designate one of those as a type. This was done by Lehtinen, Ferrara and Taiti (1998) who recently nominated S. vitiensis as the type and designated a neotype. However, no description was given. Since it was not possible to examine the neotype, the determinations made here followed that of Green (1961, p. 357), as this was the most recent and comprehensive diagnosis. Green followed the diagnosis given by Verhoeff (1926) as did Vandel (1973a, p. 132). The principle determining character is that of a conspicuous inner lobe on the lateral border of pereonal epimeron which is continuous with the lateral border of the epimeron. In the species described here, the inner lobe extends as far as (Spherillo sp. 3), or further than (all other Spherillo spp.), the posterior angle of the epimeron 1. A full diagnosis is given in subsection 3.17.3.

The genus Acanthodillo was created by Verhoeff (1926) for a species from New Caledonia. Since then, eight more species have been added to the genus. The type species A. erinaceous Verhoeff, 1926 is from New Caledonia and there is one species from New Zealand, A. spinousus (Dana, 1853), originally one of the four species described by Verhoeff when instituting the genus Spherillo. The other seven species are from Australia.

Baker (1913) described two species (A. commensalis and A. minutes) from South Australia. Vandel (1973a) transferred these two species from Cubaris to Acanthodillo along with A. brevicornis (Budde-Lund, 1913). As Lewis (1998b, p. 713) pointed out, the description of A. brevicornis was very brief and Vandel allocated it to the genus based on a drawing of the antenna alone. Therefore, the position of this species remains

[10] This homonymy was resolved by Lilljemets and Wilson (2002) who renamed the species C. lewisae.

uncertain. The genus also includes A. tuberosus (Wahrberg, 1922), which Green (1961) excluded from its original genus Spherillo based on the shape of the uropods. Verhoeff (1926) had previously connected this species to his genus Acanthodillo. A. brevicornis is from New South Wales and A. tuberosus is from Queensland and both species are known only from the type localities.

More recently, Vandel (1973a) described A. formicarum Vandel, 1973 from New South Wales and Lewis (1998b) described three new species: A. agasketos, from the Kimberley region of Western Australia; A. kioloa from New South Wales; and, A. barringtonensis from Barrington Tops National Park in New South Wales. Of the nine species detailed here, five of them are known to occur with ants (A. commensalis, A. formicarum, A. minutus, A. kioloa and A barringtonensis) while A. agasketos was collected from pitfall traps set for ants (Lewis, 1998b).

Lewis (1998b) highlighted three important characters that did not agree with previous diagnoses of the genus. The first two relate to A. agasketos from the Kimberley, which had a high frontal lamina and an hourglass shaped telson with an extreme medial constriction whilst the third, and probably more significantly, relates to A. kioloa which had ventral lobes on pereonal epimera 1-3 lobes. Despite these being uncharacteristic, previous diagnoses had not excluded these characters. Similarly, A. formicarum is uncharacteristic in that it lacks a row of horizontal ridges at the junction epimera/tergite junction and scales. Lewis (1998b, p. 713) noted that "their morphological appearance is immediately recognisable as belonging to the genus" and to accommodate her three species Lewis defined the genus thus: "short thickset antenna with eccentrically inserted flagellum; dorsal surface usually with prominent ornamentation or tubercles, spines, crests and scales; ventral lobes on epimera 1-2 or 1-3; eye often small of 2-3 ommatidia, but may have up to 20 ommatidia; epimera 1 may be split posteriorly; posterior angle between epimera and tergites often acute, sides of telson may be parallel or with central constriction; pseudotrachae present in pleopods 1-5". (p. 714).

Clearly, a number of characters are vague here and none, except for that of the eccentrically inserted flagellum, is truly definitive. The characters are adaptations to living in endogean environments, particularly the short antenna, small eyes and the development of dorsal bumps of tubercles. The character of endolobes and the number of pereonal epimeron displaying them does not normally differ within genera of Armadillidae. Whether or not the antennae are short and thickset is largely at the discretion of the person making the determination. This could be said to apply to A. agasketos (Lewis, 1998b p. 715 fig. 48) but possibly not to A. kioloa (Lewis, 1998b p. 715 fig. 57). It is not possible to comment on the form of antenna of A. barringtonensis since this is not figured. Despite these shortcomings, the genus is distinctive in its general morphology and there are unavoidable similarities between species found in the study area and those described by Lewis.

The question of scales is probably the most important. The type species A. erinaceous Verhoeff, 1926, from New Caledonia has very distinctive scales (S. Taiti. Pers. comm., 2002). This is clearly an important generic character not accounted for in the diagnoses given to date.

3.2.5. OTHER RELEVANT TAXONOMY

Lewis and Green (1994) reviewed the monogeneric family Actaeciidae. The work included a description of four new species bringing the total number of species to eight, six from Australia and two from New Zealand. The distribution of A. pallida, the Western Australian species, was extended to cover an area from Kalbarri in the north, to near Adelaide in South Australia. In the eastern part of its range the distribution of A. pallida overlaps that of A. thomsoni Green 1966. The paper included a key to the species and some SEM imagery of a specimen from Esperance in Western Australia The paper was a useful biogeographic analysis at a continental level and identified a new species (A. bipleura Lewis & Green, 1994) from Tasmania previously thought to be A. pallida (Green, 1961). Schmidt (2002a) subsequently included Actaecia in the family Scyphacidae sensu str. because it formed a monophyletic group with Scyphax. This chapter was completed by the time this paper was published so the family Actaeciidae is used here.

Despite the work of Nicholls and Barnes (1926) and Lewis and Green (1994), the knowledge of the regional littoral Oniscidea is scant. The genus Tylos, a highly characteristic genera of littoral isopods, contains about twenty-four species, nine of which are from the southern hemisphere and of restricted distribution (Lewis, 1990). While none have been recorded from south-western Australia, one species, T. australis Lewis & Bishop 1990, is known from Victoria and New South Wales, another, T. bilobus Lewis, 1990 is known from beaches in Queensland and a third, T. tantabiddyi Lewis, 1991, from the Exmouth peninsular in northern Western Australia.

The Western Australian form differs significantly from its nearest geographical relative T. nudulus Budde-Lund 1906 from Christmas Islands (Lewis, 1991). The widespread distribution of the genus suggests that it is likely to be present in south-western Australia. The localised distribution of other Tylos spp. suggests that new species might also be present. Other supra-littoral Oniscidea are also poorly represented in the literature, particularly the south coast of Western Australia.

The secondarily aquatic genus Haloniscus has received a little more attention. Prior to 1995 two species were known, H. searlei from salt lakes, ranging in salinity between 8 and 159‰ (Williams, 1970) across most of the southern continent of Australia, and H. stepheni from terrestrial habitats, although adjacent to salty creeks, in the Pilbara region of Western Australia (Nicholls and Barnes 1926a). Recent work has added to this a new species from anchialine waters in a cave in New Caledonia (Taiti, Ferrara & Illiffe, 1995), extending considerably the distribution of the genus, and three new species from both fresh and saline groundwater calcretes in the Pilbara region (Taiti and Humphreys, 2001).

As part of this latter work, a redescription of H. stepheni revealed that is not a species of Haloniscus but of the genus Andricophiloscia Vandel 1973 (Philosciidae).

The work of Humphreys and co workers has resulted in the description of some other new species, all from cave systems in northern Western Australia. Dalens (1992) dealt with the genus Buddelundia from caves of the semi-arid Cape Range in northern Western Australia. One species, B. cinerascens, also occurs in coastal parts of the north of the region. Four new species, B. grisea, B. hirsuta, B. humphreysi and B. zebricolor, and one sub-species, B. zebricolor fulva were described. None of these species were true troglobites as all were found outside caves and show none of the expected morphological adaptations. Later, Dalens (1993) described two new genera of Armadillidae from inside caves in the Kimberley and Barrow Island: a primitive, non-rolling armadillid Kimberlydillo waldockae and Barrowdillo pseudopyrgoniscus. B. pseudopyrgoniscus is significant in that it has an arrangement of the pleopod exopodites previously thought unique to Buddelundia. The genus differs from Buddelundia in a number of characters, principally the lack of a schisma on pereonal epimeron 1, elaborate dorsal ornamentation and horizontally extending epimera. The character of the arrangement of the pleopods places it the sub family Buddelundiinae, which was previously thought to be monogeneric.

3.2.6. SUMMARY

The region's Oniscidea have been dealt with sporadically and have never been considered as a whole or in a global context. With very few exceptions, the only descriptions available are the original ones, rarely in English and without including characters that are now considered commonplace. The first descriptions made of the region's Oniscidea made by Budde-Lund (1912) were unfinished and even later work by Vandel (1973a) has been found by other workers to contain significant errors. Most of the Armadillidae described for Australia, with the exception of Buddelundia and even those by Lewis recently (1998a, 1998b), although valuable, are considered to be in the wrong genera (S. Taiti, pers. comm. October, 2002). This has been demonstrated by Lillemets and Wilson (2002) who re-examined material described by Lewis (1998a). Confident generic placement of species was only possible after examination of the type species of a number of genera. Since these are often very old, lost or were not nominated, the task of adequately describing even a few taxa is enormous. However, this does not preclude a biogeographical analysis of the region's Oniscidea, but it does not allow for a comprehensive comparison of wider phylogenetically based biogeographical relationships, even from a continental perspective.

The following sections demonstrate that using a limited range of characters, limited examination of type material and, despite the encumbrances of problematic taxonomy, it is possible to undertake a meaningful examination of the Oniscidea and to draw valuable conclusions from such an examination. The designation of genera in particular is problematic and all genera assigned here, particularly the Armadillidae, are very tentative indeed. These are made largely on the existing descriptions in the literature, many very

old, and without opportunity to examine or designate type species. Nevertheless, the systematic relationships between the Oniscidea described here are both striking and obvious. The following section outlines the methodology by which this systematic analysis was undertaken.

3.3. TAXONOMIC METHODOLOGY

The methodological framework, into to which these methods fit, was given in Chapter 2. This section describes how the taxonomic work was undertaken. Prior to this study, the author had little or no knowledge of terrestrial isopod biology or morphology. Therefore, a good deal was learned both before and during the process of determining taxa. Learning on the job, so to speak, has resulted in rather a protracted methodology. Constant revision of diagnoses was made as taxonomic understanding developed and literature became available. New characters were continually devised and the validity of others questioned.

Following the methodology, the remaining parts of this chapter deal with the construction of a key (Section 3.5), the character states used in the key (Section 3.6) and descriptions of the taxa (Section 3.7). The purpose of the following sections is not to provide a finite list of species for the study area but to determine taxa which are relatively easily recognised and can be determined using any combination of the key, characters, and descriptions given. The overall methodology in constructing these is described in five stages. These represent the fact that taxonomic expertise was gained throughout the project. The methods followed are obviously different to those of someone who already had such expertise. One of the lasting strengths of this taxonomic approach is that the author was acutely aware, from a very early stage, of the need to present illustrated descriptions of characters and use clear and consistent terminology. Consequently, the reader need not have specialist taxonomic training to find the key and the descriptions accessible.

3.3.1. STAGE ONE

The first stage of the process involved sorting, curation and databasing the Oniscidea within the WAM. The crustacean collection was sorted in order to locate all terrestrial isopod material and secondly to determine which material had been collected from Western Australia. Most of the material required rebottling and had not been examined for some considerable time. Specimens were routinely re-bottled and new labels were written where necessary. Each was given a unique number so it could be identified later A DBF format database, compatible with those used at the WAM, was established which included the unique number, taxonomic, locality and microhabitat data. All material was databased according to information present on the accompanying labels. New fields were added as necessary to accommodate new types of information. Specimens that had already been registered and were present on the WAM Crustacea database or in the ledgers were included. No detailed examination, other than that required to ensure the

satisfactory preservation of the material, was undertaken at this time. However, notes were made as to the general morphology of specimens. Literature relating to the taxonomy of the region's Oniscidea was compiled and the taxonomic, chronological, locality and habitat data that were included in the papers was attributed to the appropriate taxa on the database. Principle taxonomic characters were determined from the literature at this stage. This initial part of the work took about four months.

3.3.2. STAGE TWO

At the completion of stage one, it became apparent that field collection of material was necessary. Following the addition of such material, specimens from outside the then defined study area were returned to the main WAM collection, and an examination of all relevant material (about 800 jars) was made. Much of this stage involved sorting vials containing many specimens of different species both from the museum and field collections. Preliminary determinations of family were carried out from characters developed from the literature and from notes made in Stage 1. The different taxa were separated and the database updated to include new records for vials containing more than one taxa. Characters were primarily: the number of articles of the flagellum of the second antenna; the ability to conglobate; the degree to which the body outline is interrupted between the pereon and pleon; and, the presence/absence and number of pleopodal lungs.

3.3.3. STAGE THREE

This stage involved an examination of each of the families in turn. It was soon evident that species determination was, in most cases, not possible from the taxonomic literature. Given the amount of material collected and examined from the WAM collection, it became evident that, in order to deal with all the material, dissection, mounting and examination of some characters by means of a compound microscope, would not be routinely possible. Therefore, it was decided that all taxa would be determined using a range of external morphological characters normally visible under a dissecting microscope with some manipulation of specimens and minimal removal of obstructing appendages. Consequently, character states were identified for each of the families in question and preliminary descriptions with regard to these characters were made for each of the specimens examined. Males and females were examined where both were present in a sample and any sexually dimorphic characters were noted. The variation in characters states between specimens and in ontogenetic series were also documented where evident. This stage resulted in a list of usable characters states for each family.

3.3.4. STAGE FOUR

Following an examination and description of relevant type material in the WAM, taxa were determined using the characters listed in Section 3.6. A specific determination was made only when all characters examined were consistent with type material examined, or with the literature where descriptions permitted it, and where only externally visible characters

were required. Cosmopolitan species introduced to the region were identified using the key published by Hopkin (1991) or where determinations of identical taxa had been made previously by recognised oniscidean taxonomists. Taxa were determined and reference specimens retained for each new taxon as they appeared. Voucher specimens were selected from among field or WAM material to replace type specimens in order to avoid unnecessary handling of the very old and delicate type material. Voucher specimens were identical to the types and came from the same locality. All specimens were then examined and compared to the most similar voucher specimen(s). When jars contained more than one taxon records were added to the database as appropriate.

Specimens were constantly re-examined during this stage. Progress was by no means linear. All species, and sometimes whole families, were periodically re-examined both as characters were refined and as conversancy with the literature increased. At the end of this stage, preliminary descriptions of all taxa were made.

3.3.5. STAGE FIVE

Following the determination of as many specimens as time permitted, representative specimens of each taxon were selected for photographing. The specimens selected for photographing were not necessarily those used as voucher specimens during determination. Consideration was given to the condition of the specimen and the degree to which the important characters were visible on that specimen. For described species, a representative from a locality close to the type locality was chosen since this was considered to be most likely to represent the type material. One or more specimens were chosen if some character states varied within a species.

Images of each taxon were taken using an Olympus DP 10 digital camera mounted on an Olympus SZH research stereo microscope at various magnifications. Original images were 1280 by 1024 pixels at 144 dpi in JPEG format. The clearest of a number of images taken were selected for final use. These were captured via a flash card and manipulated in Adobe Photoshop V.5. Images were enhanced using the following methods. Backgrounds were blacked out and RGB colour levels were adjusted to optimise discrimination of the desired characters. Images were cropped, enlarged or reduced prior to compiling montages of each taxon. Some images were reversed or inverted to allow for the optimal spatial arrangement of images, but dimensions were not distorted. Each finished montage was saved in JPEG format at 300 dpi and was approximately 1650 by 1650 pixels. Character state codes were added to each image in Photoshop and the resulting image was flattened, saved again in JPEG format, and subsequently inserted into this document. Where important character states varied considerably within a taxon, and in order to show geographical variation of specimens, more than one montage was prepared.

Images used for the illustration of character states (Section 3.6) were selected from the original images and not from the final montages. Consequently, some images that

appear in Section 3.6 are different to those in the montages in Section 3.7 despite being of the same specimens. The images were treated in the same manner as the montages but were smaller, 531 by 531 pixels at 300 dpi also in JPEG format. Some images were modified from those prepared by other authors; these were scanned and modified in Photoshop. Where this occurred acknowledgment has been given in the appropriate plate caption. All arrows and labels were added subsequently in Photoshop.

A key to the taxa had been in preparation throughout the taxonomic work project but was finalised after the colour plates had been produced. Considerable care was taken to ensure that the characters used in the key could be clearly illustrated. WAM registration numbers were allocated to all specimens following finalisation and testing of the key and final descriptions were prepared for each taxon. Species which had not been determined at the genus or species level were assigned morphospecies. The use of family and generic names is representative of the current state of taxonomy; no attempt to correct all of these was undertaken at this stage. Where the characters used do not permit a genenc diagnosis the taxon is given only a family determination and a consecutive number.

3.4. DEVELOPMENT OF THE KEY

3.4.1. GLOSSARY OF TERMS USED IN THE KEY

The terminology and nomenclature in this work follows Holdich, Lincoln and Ellis (1984). The general morphology of a terrestrial isopod is illustrated in Figure 3.2. Alternative terms commonly found in the local literature for the parts described are given in parentheses. Only the terms used in the list of character states, key and diagnoses, and those critical to understanding the review of the taxonomic literature are given here. Some detailed and highly specific characters are illustrated only in Section 3.6 and are not included in the glossary. The primary purpose of the glossary is to provide an overview of terrestrial isopod morphology to allow for the successful location and interpretation of the character states used in the key.

The body of a terrestrial isopod is divided into three main sections: the head (cephalon), the pereon (peraeon, perelon, mesosome, thorax, truncus) and the pleon (abdomen, metasome, truncus). The term pleotelson is also used to include the pleon, the uropods and the telson (terminal segment). The term pleon, as used here, excludes the uropods and telson which are considered separately.

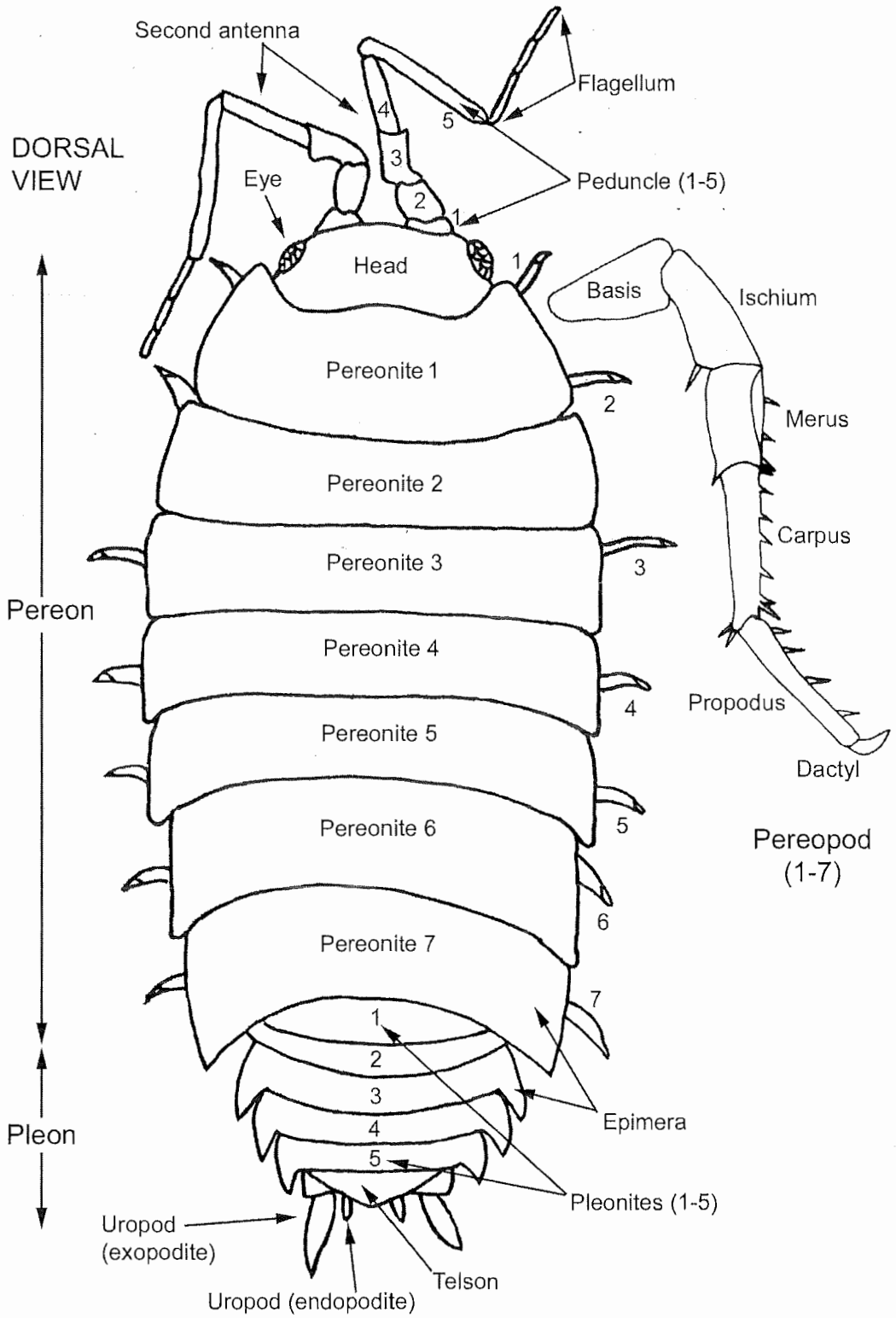


Figure 3.2. Glossary of dorsal external morphological characters of a terrestrial isopod.

3.4.1.1. The head

The head bears two antennae. The antennule (antenna 1) is very small and is located adjacent to and just inside the antenna (antenna 2). The antenna consists of a five jointed peduncle and a flagellum of a varying number of articles (sections). The flagellum is identified by a characteristic bend in the antenna, most obvious in live animals. The head may have lateral or frontal lobes, a fontal ridge or frontal processes. The central frontal part of the head is called the profrons. The mouthparts, although they are not described in the key or character states, are important and should be clarified. Mouthparts consist of a pair of mandibles, maxillules (maxilla 1), maxillae (maxilla 2) and maxillipeds (maxillipede). The structure of each of these is complex and it is not necessary to detail them here. The clypeus forms a line above the mouthparts and runs between the second antennae. This may have lateral processes or lobes at each end. Some species have an additional line above the antenna, but below the frontal line or ridge, called a supra-antennal line. Eyes, if present, are composed of one or more ommatidia (ocelli) and are situated on the lateral margins of the head.

3.4.1.2. The pereon

The pereon is composed of seven segments, each of which has a pair of pereopods (peraeopod, pereiopod, leg). The description of the various parts of each pereonite (an individual segment of the pereon) is often confusing. The dorsal plate of the pereonite is termed the tergite and each pereonite has a lateral portion called an epimera. The inner margin of the epimera, or the junction of the epimera and tergite, is at the point of the pereopod muscle attachment, hence the term coxal plate. The epimera are fused to the tergites in all Oniscidea except the Tylidae. The underside of some conglobating (able to roll up) Oniscidea have interlocking lobes (articulatory lobes, endolobes) used to lock epimera, and hence the pereonites, whilst rolled up. These lobes are sometimes joined to the lateral margin of the epimera and form a schisma on the posterior lateral corner of the epimera. Either a sulcus arcuatus or sulcus marginalis can be found on the first pereonal epimera. These are longitudinal grooves running either parallel to the lateral margin or along the ventral margin of the epimera respectively. Both are illustrated in detail in the next section.

3.4.1.3. The pleon

The pleon consists of five segments. In some Oniscidea, the pleonites may also have epimera (pleura). To avoid confusion, where epimera are mentioned in this work they are preceded by either pereonal or pleonal. The ventral surface of the pleon has five pairs of appendages called pleopods. The ventral surface of the pleon of a typical rolling and non-rolling female isopod is illustrated in Figure 3.3. The pleopods have endopodites (endopods) and exopodites (exopods). In some Oniscidea, the exopodites are adapted for aerial respiration by means of pleopodal lungs (pseudotrachae, lungs). In other cases, respiration takes place in endopodal gills. In males, the first and second pleopod

endopodites are adapted for copulation and are visible in ventral view. The uropod consists of a basal part, the protopodite, with an endopodite and exopodite. The exopodite is reduced or absent in some taxa.

Noduli laterales are found on the dorsal surface of all three sections of the animal and are long dorsal sensory setae. They are longer than ordinary setae and emanate form a small round circular pit. They are usually visible under a dissecting microscope and for taxa described here, where present, are situated near the lateral margin of the pereonal epimera.

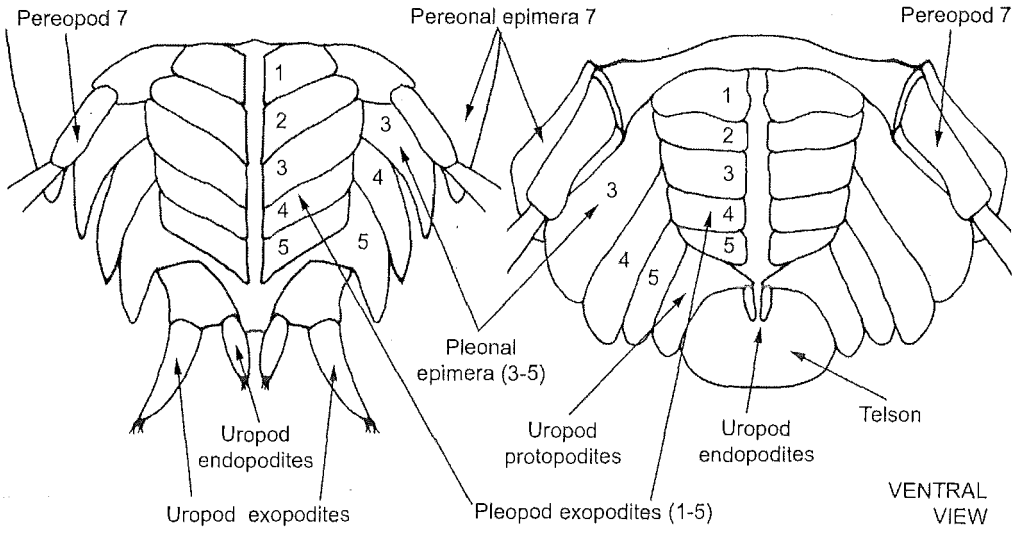


Figure 3.3. Glossary of external ventral pleon characters of a female non-rolling (left) and a female rolling (right) terrestrial isopod (pleopod endopodites are not visible).

3.4.1.4. Juveniles

The growth of terrestrial isopods occurs in a series of stages (stadia) in which first the posterior part (pleotelson and pereonites 5, 6, & 7) moults followed by the anterior half (head and pereonites 1, 2, 3 & 4) a few days later. There are slight morphological differences between the growth stages of terrestrial isopods; however, these are not as marked as in some insects (Holdich et al., 1984). The early ontogenetic stages of terrestrial isopods have been given various different names and were summarized by Holdich et al. (1984). The growth and development of live young within the marsupium and their release is as follows: fertilized eggs – embryos – marsupial mancas - postmarsupial mancas (newly released young) – juveniles. Juveniles and second stage post marsupial mancas differ from first stage post marsupial mancas by the presence of the seventh pereonite and its appendages, which develop only after the first moult. Juveniles are generally recognisable by their smaller size, pale colour, and more prominent eyes relative to other features. Early stage juveniles and mancas cannot be identified by this or any other key. Late stage juveniles examined during this study

resemble the adult form, although care should be taken when assessing the ratio of length to width and the degree of tuberculation on the dorsal surface. The key is only reliable for adult specimens.

3.4.1.5. Colour

Colour has been used as a character but only in a very broad sense and usually in conjunction with other characters. Specimens lose colour during the preservation process and continue to lose colour when stored in ethanol over time. Preserved specimens can also differ in colour to live specimens. Therefore, any mention of colour made in the key or descriptions refers to colour when preserved in 70% ethanol. Therefore, for when identifying specimens that have been preserved for a long time, colour should not ne used a diagnostic character. Broad discrimination is made between colour types in various parts of the key. These should be considered in association with the colour plates created specifically to show these differences. While colour of the final plates will obviously be influenced by all stages of the production process, every effort was undertaken to ensure that the final images represented, as close as possible, the actual colour of the specimens examined.

3.4.1.6. Size

The issues of overall size can be problematic. The length of live specimens can differ slightly from preserved specimens due to muscle contraction, or relaxation, during the process of preservation. The length of specimens, measured from the front of the head to the tip of the telson, is given in each of the plate captions. Since the plates contain illustrations of various parts of the specimen at various magnifications, no scale is given on each plate. The reason for including size is because there are some considerable size variations between the taxa; the difference between the smallest and largest species is at least one order of magnitude. For obvious reasons, measuring the length of conglobating taxa can be difficult. The lengths given for conglobating species are for the unrolled or flat state. This was determined by unrolling the specimens photographed or measuring unrolled specimens of identical size where available. All specimens illustrated are typical of the maximum size obtained for individuals of that taxon. Specimens were measured to the nearest 0.5 mm under a dissecting microscope whilst resting on a slide with grid squares of 1 mm.

3.4.2. OVERVIEW OF THE KEY, CHARACTERS AND TAXA DESCRIPTIONS

The key is intended to be used not only by workers familiar with the Oniscidea, but also by workers dealing with terrestrial invertebrate ecology in general. Terrestrial isopods are a conspicuous component of the terrestrial invertebrate fauna of south-western Australia. This taxonomic work and the microhabitat detail analysed subsequently will enable the group to be more useful in ecological studies than it has been in the past, therefore providing a significant contribution to ecology-based environmental management. To this end, a traditional dichotomous key (Section 3.5) is accompanied by two other interrelated

parts: a fully illustrated list of the character states used in the key (Section 3.6), and a diagnosis, illustration, and list of the specimens examined (Sections 3.7 – 3.17). The list of character states, described and figured in Section 3.6, is central to the function of the key and fundamental to the descriptions of the taxa.

There were a number of reasons for the selection of the characters used in the key. Schmalfuss (1984) correlated terrestrial isopod morphology, habitat and behaviour and determined what he called eco-morphological strategies. An account of the phylogenetic significance of these "habitus" types was given by Schmidt (2002a). They were defined by a number of simple morphological characters, of which body shape and the nature of the dorsal surface are paramount. Therefore, characters included here distinguish easily between "habitus" types. This is achieved mainly by Section 3. 6. 1, which illustrates general morphological characters. For each of the taxa descriptions, I have included an indication of the "habitus" type. The types, sensu Schmalfuss (1984) with additional observations from Schmidt (2002a), are "runner", "clinger", "creeper" and "roller". They are summarised as follows:

Runners have long pereopods and second antennae, a smooth dorsal surface and a pleon that is distinctly narrower than the pleon. They escape predators (or oniscidologists) by running away at high speed.

Clingers have enlarged pereonal epimera and sometimes pereonal epimera of pleonites 3, 4 & 5. They are flatter and broader and keep the lateral margins of their body firmly in contact with the substrate. This reduces water loss by evaporation, reduces the vulnerability of the soft ventral surface to predators and also makes them less visible to predators (or oniscidologists).

Creepers are small and cylindrical with short pereopods and sometimes with longitudinal ribs on the dorsal surface. They are therefore well-adapted to endogean habitats since these specific body constructions enable movement through narrow interstices. The tergal ribs function to minimise possible contact area with the wet substrate in order avoid adhesion by the forces of water. According to Schmidt (2002a) this is a derived condition.

Rollers have evolved the ability to conglobate. This has happened convergently a number of times within the Oniscidea (Schmidt, 2002a). The ability to conglobate is often accompanied by a number of other adaptations such as lobes on the ventral surface of some pereonal epimera that lock with the anterior margins of the adjacent epimera and modifications of the uropods. Some rollers also have expanded pereonal epimera and a tendency to adopt a creeping habit when not enrolled. The advantage of rolling is to protect the ventral area and to make it harder for potential predators (or oniscidologists) to pick them up.

The rationale for all characters used was that they should be unequivocal, accessible and capable of photographic reproduction. This was essential in order for the key to be used

successfully by non-specialists. Therefore, all characters used are visible using a dissecting microscope without the prerequisite of dissection. A good deal of manipulation of both specimens and lighting is sometimes required to view a character but these depend largely upon the equipment, skill and preferences of the individual. The glossary and illustrations of the character states should provide reassurance to the user that the key has been interpreted correctly. I have endeavoured to show the variation within one character by illustrating all variations from the same angle. However, due to gross differences in the sizes of the specimens, and therefore variation in magnification, this was not always possible. In all cases, I have used the clearest image available even if it meant showing variations of a character state from different angles. Where the key requires the determination between the presence and absence of a character, sometimes only the variation of the presence of the character is illustrated. The alternative choice is then the absence of the feature shown in the illustration. Characters derived from the literature that fitted the above criteria were included in the key.

3.4.2.1. Interpreting the character states

Forty morphological characters were used to determine taxa and the variation within each character is illustrated. Character states were grouped according to the part of the animal in which they occur (General morphology, head, pereon, pleotelson). Each subsection of Section 3.6 deals with a different part of the animal and characters are coded anteriorly to posteriorly according to their position. Characters relating to general morphology are preceded with Gm, characters relating to the head are preceded with He, characters relating to the pereon with Pe, and characters relating to the pleotelson with Pl. The key uses the most obvious and simplest of characters first. Where character variations are used in the key the appropriate code appears in parentheses (e.g. He 1.1). The characters used to key-out taxa are also provided on the colour plates given with taxa descriptions in Section 3.7.

Section 3.6 is simply a list of colour plates describing a character state. Each subsection of Section 3.6 contains the character states relevant to a part of the terrestrial isopod anatomy (e.g. Subsection 3.6.3 contains all characters of the pereon (Pe) and its appendages).

The heading of each sub-subsection describes the character state in question. For example, Sub-subsection 3.6.3.6 shows the variation in the sixth character of the pereon (Pe 6). The states of all characters are then illustrated in each sub-subsection by means of a colour plate. It was not considered necessary to give a written description of each of these since this is done in the key and taxa descriptions where appropriate. The point at which each variation of a character state was used in the key is shown underneath each plate. For example, the second variation of character state Pe 6 (Pe 6.2) was used in Key F at stage 13 and was choice a (F13a). Figure 3.4 shows how to interpret the subsection headings and coding used in the key, character plates and taxa descriptions.

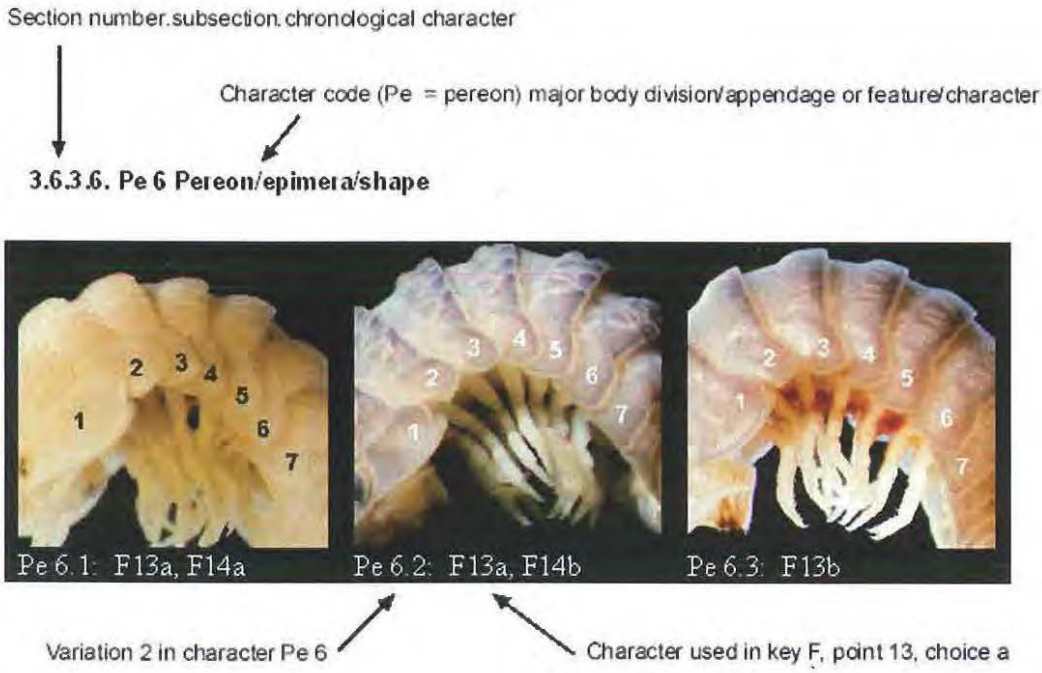


Figure 3.4. How to interpret the codes used in the remaining sections of this chapter.

3.4.2.2. Interpreting the key

The key is set out in seven tables (A-G), each dealing with a different taxonomic group. Each part of the key has a number of alternative choices (stages). Therefore, the first stage of the second part of the key is B1 and the choices are B1a and B1b. In the normal manner, the choices either lead to a particular family species or genus and/or to another key, or a subsequent stage of the same key (e.g. B2). The number of taxa resolved in each stage of the key is also given at the top of the key.

The key is dichotomous in that it allows for two choices at each point. However, there are two instances where a character state dictated three obvious choices. The first part of the key (A) resolves the introduced and littoral taxa and the families that go on to form the following six sections (B-G). It is important to recognise introduced taxa from indigenous ones, and since they are quite different in a number of simple characters it was desirable to achieve this first and foremost. Furthermore, resolution of taxa to family level is often adequate. Only indigenous non-littoral species are used in the biogeographical analyses that follow this chapter so, for this reason also, littoral and introduced taxa are recognised first.

In each stage of the key, a number of characters are used to make choices. Where the character state is illustrated, its code is given in brackets in the key. As stated, these

codes match those used in the section preceding the key which lists and illustrates the characters (examples of coding was given in Figure 3.4). In early stages of the key, the user may be asked to choose a single variation of a character state from many alternative variations. In this case, a range of character state codes is given in brackets. The illustration used for these characters at early stages of the key may be repeated for characters at a later point as the choice of characters narrows. For example, the first part of the first key asks whether the flagellum of the second antenna has two articles or not. The illustration used to show this character is used again later to illustrate the relative lengths of these two articles. Clearly a different character, but the same illustration suffices. Including coding in the key allows for an evaluation of each character state at each stage in the key. Used in conjunction with the glossary, this allows for an unequivocal discrimination of character states. The illustrations of the character states also include reference to the point or points at which they are mentioned in the key (See Figure 3.4). This allows for distinctive characters to be assessed immediately and the key commenced at an appropriate point if required.

3.4.2.3. Interpreting taxa descriptions

Each of the sections 3.7 to 3.17 deals with a family, each subsection therein with a genus and sub-subsection with a species. Each taxon description follows the accepted layout; each sub-subheading is followed by a list of plates, synonymies, material examined, a diagnosis, any relevant taxonomic remarks and a colour plate. Characters detailed at the family or generic level obviously apply to all taxon included in that section and are therefore not repeated in the specific diagnoses. References are given where reliable or more complete diagnoses are available.

The character state illustration codes are also included on the illustrations of each of the taxa. All the character states used to key out an individual taxon are included alongside the part of the animal to which that character refers. In this way, the illustrations of the character states can be used to provide a detailed view of a particular character of an individual taxon. The list of plates for each taxon also includes the plates where the taxon in question was used to illustrate a character. Some taxa are in a slightly different order to that which they were resolved in the key. This is to accommodate their description in the appropriate genera and also to reflect late changes made to the key following testing.

The lists of material examined includes the WAM Crustacea section registration number prefixed by a "C", the locality at which the specimen was collected, decimal latitude and longitude coordinates, the surname and initial(s) of the collector, the date of collection in dd-mm-yy format and coded microhabitat information. Where any information was not known, it is signified by question marks (??) or omitted. Where specimens were collected over an extended time period, such as pitfall traps, the latest date of collection is given. The codes used to describe microhabitat are given later in Table 4.2 in Section 4.2. If microhabitat information was not known, it was omitted from list of material examined.

The section describing the taxa concludes with a list of taxa and the number of records for each one. This provides a basis for the following chapters which go on to examine diversity and biogeography. Since littoral and introduced taxa are not discussed in Chapters 4-8, a brief review of their distribution and ecology is given at the end of this chapter.

3.4.2.4. Identifying taxa

The key was developed for publication in both print and electronic media. Whilst the key itself is descriptive and inclusive enough to be used alone, the addition of digitally illustrated taxa and character states, makes it a relative simple step to publish it electronically. The nature of cross-referencing of character states allows for the hyper-linking of the key to characters, characters to taxa and vice versa. The strength of the key in both its printed and potential electronic form is that can be accessed in three ways:

1. Taxa can be determined in the traditional way by following the sections of the key (Section 3.5) in the order given;
2. Unique or distinctive characters can be evaluated by reference to the list of illustrated characters (Section 3.6) which then refer the reader directly to the appropriate part of the key; and
3. Taxa may be interim determined by comparison with the comprehensive illustrations of the taxa (Section 3.7-3.17) and verified by a more a detailed examination of the important characters given by the codes accompanying each illustration, and verified by the key if necessary.

The key, character states and the descriptions of the taxa now follow.

3.5. THE KEY

3.5.1. PART A. FAMILIES, LITTORAL, AQUATIC AND INTRODUCED TAXA (11 TAXA)

A1a	Flagellum of antenna 2 comprised of 2 articles (He 1 1, He 1.2, He 1.3).	A9
A1b	Flagellum of antenna 2 comprised of more than 2 articles (He 1.4 - He 1.10).	A2

A2a	Flagellum of antenna 2 with 10 or more articles (He 1 4). Eye with more than 100 ommatidia (He 4 1). Uropods very long (Pl 4.1). Littoral species.	Ligia sp.
A2b	Flagellum of antenna 2 with more than 4 but less than 10 articles, conical and with a tuft of setae at its apex (He 1.5). Eye of no more than 3 ommatidia (He 4.2, He 4.3). Uropods not as Pl 4 1 Non-littoral species.	PART B STYLONISCIDAE
A2c	Flagellum of antenna 2 with 3 or 4 articles (sometimes difficult to distinguish as distal article 4 can be very small) (He 1.6 - He 1.10). Eye with more than 3 ommatidia. Uropods not as Pl 4.1.	A3

A3a	Able to roll up into a ball (conglobating) (Gm 1.2). Posterolateral part of uropod protopodite flattened and extending beyond telson (Pl 6.1). Therefore, telson not forming part of body outline of pleotelson. Littoral species.	Actaecia pallida
A3b	Unable to roll up into a ball (non conglobating) (Gm 1.1). Uropods long and tapering or spear like and extending well beyond body outline (Pl 4.2, Pl 4.3, Pl 4.4).	A4

A4a	Flagellum of antenna 2 with 3 articles (He 1.6, He 1.7).	A7
A4b	Flagellum of antenna 2 with 4 articles (He 1.8, He 1.9, He 1.10).	A5

A5a	Body outline interrupted at junction of pereon and pleon (Gm 3.1). Carpus of pereopod 1 very broad (Pe 17.1). Head without prominent lateral lobes. Pleopod exopodites broad and rounded overlapping in the centre sometimes visible in dorsal view (Pl 2.1). Secondarily aquatic species occurring in or near salt water.	Haloniscus searlei
A5b	Body outline not interrupted at junction of pereon and pleon (Gm 3.2). Carpus of pereopod 1 of not broad (Pe 17.2). Head with prominent lateral lobes (He 7.1, He 7.2). Pleopod exopodites not broad or rounded, not overlapping in the centre and never visible in dorsal view. Littoral species.	A6

A6a	Pereonites smooth with pigment visible as individual chromatophores (Gm 2.1). Head with lateral lobes broad and rounded (He 7.1). Posterior margin of pereonal epimera 1 straight not angled backwards (Pe 10.1).	Alloniscus pallidulus
A6b	Pereonites bumpy without pigment visible as individual chromatophores. Head with lateral lobes squarish (He 7.2) and with triangular central projection (He 7.4). Posterior margin of pereonal epimera 1 angled backwards (Pe 10.2).	Deto marina

A7a	Antenna very long, more than two-thirds length of animal (He 12.1). Uropods long with exopodite much longer than endopodite (Pl 4.2). Confined to marine and estuarine coasts.	Halophiloscia couchii
A7b	Antenna long but never more than half length of animal (He 12.2). Uropods of moderate length with exopodite only slightly longer than endopodite (Pl 4.3, Pl 4.4). Not confined to marine and estuarine coasts but may be found there.	A8

A8a	Body outline not interrupted at junction of the pereon and pleon (Gm 3.3). Pereonites without noduli laterales	Part D ONISCIDAE
A8b	Body outline interrupted at junction of pereon and pleon (Gm 3.4). Pereonites with noduli laterales (Pe. 1.26).	Part E PHILOSCIIDAE

A9a	Unable to roll up into a ball (non conglobating) (Gm 1.1). Uropods long and tapering or "spear-like" and extending well beyond outline of pleotelson (Pl 4.3, Pl 4.4).	A10
A9b	Able to roll up into a ball (conglobating) (Gm 1.2). Uropods flattened and "spade-like" or "tooth-like" and not extending beyond outline of pleotelson (Pl 4.5, Pl 4.6).	A11

A10a	Animal shorter than 5 mm (except Australoniscus springetti) First article of flagellum of antenna much less than half the length of the second article (He 2.1, He 2.2). Pereonites covered with fine setae or scales (except Australoniscus springetti) (Pe 1.8, Pe 1.9). Exopodites of all pleopods without lungs. Telson triangular, never tapering to a point (Pl 7.1, Pl 7.2). Native species.	PART C PLATYARTHRIDAE & BATHYPROPIDAE
A10b	Animal longer than 5 mm. First article of flagellum approximately equal in length to the second article (He 2.3, He 2.4). Pereonites never covered with fine setae or scales. Pleopod exopodites 1 & 2 with lungs (Pl 3.1) visible as white patches in live animals. Telson sub-triangular (Pl 7.3) or more commonly tapering to a point (Pl 7.4). Introduced species.	A13

A11a	Without interlocking lobe structures on ventral surface of epimera of pereonite 1 (Pe 12.1). Uropod exopodite large and plate-like and contributing to body outline of pleon (Pl 5.1). Introduced synanthropic species.	Armadillidium vulgare
A11b	With interlocking lobe structures on ventral surface of epimera of pereonite 1 (Pe 12.2). Uropod exopodite small or absent, therefore uropod protopodite contributing to body outline of pleon (Pl 5.2). Native species.	A12

A12a	Pleopod exopodite 4 not significantly longer than others, therefore pleopod exopodite 5 visible (Pl 2.4) and pleopod exopodites loose and not interlocking.	PART F ARMADILLIDAE
A12b	Pleopod exopodite 4 much longer than others and expanded to cover pleopod 5 (Pl 2.5). Exopoditas of pleopods 2, 3 & 4 with grooves on adjacent margins, therefore pleopod exopodites interlocking.	PART G ARMADILLIDAE Buddelundia

A13a	Body outline interrupted slightly at junction of pereon and pleon (Gm 3.5).	Porcellionides pruinosus
A13b	Body outline not interrupted at junction of pereon and pleon (Gm 3.6).	A14

A14a	Head with large sub-rectangular central frontal projection (He 6.1). Telson sub-triangular (Pl 7.3). Introduced littoral species.	Porcellio lamellatus
A14b	Head with rounded central frontal lobe (He 6.2). Telson elongate and tapering distally (Pl 7.4). Not usually littoral species	A15

A15a	Dorsal surface of head (He 5.1) and pereon (Pe 1.1) tuberculate. Uropod exopodites relatively short and broad (Pl 5.3). Introduced synanthropic species.	Porcellio scaber
A15b	Dorsal surface of head and pereon entirely smooth, uropod exopodites relatively long and tapering, widest at the end nearest the body (Pl 5.4). Introduced synanthropic species.	Porcellio laevis

3.5.2. PART B. STYLONISCIDAE (8 TAXA)

B1a	Body outline not interrupted at junction of the pereon and pleon (Gm 3.7). All pereonites with very distinct longitudinal rows of raised bumps (Pe 1.2). Pereonal epimera extending laterally (horizontally) (Pe 8.1) and appearing discontiguous.	Notoniscus sp. nov.
B1b	Body outline interrupted at junction of pereon and pleon (Gm 3.8). Pereonites smooth, tuberculate, bumpy or setose. If longitudinal rows of bumps present, becoming less distinct posteriorly (Pe 1.3). Pereonal epimera slightly extending laterally (horizontally) or not at all.	B2

B2a	Head with poorly developed lateral lobes (He 7.3). Dorsal surface of pereon smooth with sparse evenly distributed setee. Animal laterally convex without horizontal projection of pereonal epimera (Pe 8.2).	Styloniscus sp. 1
B2b	Head with moderately or well developed lateral lobes (He 7.4). Dorsal surface of pereon with well defined tubercles, bumpy or densely setose (Pe 1.3 - Pe 1.6). Animal flatter with pereonal epimera moderately or well extended laterally (Pe 8.3).	B3

B3a	Dorsal surface densely setose and/or irregularly bumpy, animal very small (< 2 mm long). Distal articles 4 & 5 of peduncle of antenna short and very broad (He 3.1).	Styloniscus sp. 2
B3b	Dorsal surface not densely setose, animal small but greater than 2 mm long. Distal articles 4 & 5 of peduncle of antenna not short and broad (He 3.2, He 3.3).	B4

B4a	Pereonites 1, 2 & 3 with bumps arranged in longitudinal rows (Pe 2.1, Pe 2.2) usually more evident close to the longitudinal midline.	B5
B4b	Pereonites 1, 2 & 3 irregularly bumpy or with well-defined rounded tubercles not arranged in longitudinal rows (Pe 2.3).	B7

B5a	Head with prominent sculpturing (He 5.2).	B6
B5b	Head bumpy but without prominent sculpturing (He 5.3).	Styloniscus sp. 3

B6a	Animal broad (Gm 4.1) and longitudinal rows of bumps on pereonites 1, 2 & 3 prominent (Pe 2.4).	Styloniscus sp. 4
B6b	Animal slender (Gm 4.2) and longitudinal rows of bumps on pereonites 1, 2 & 3 less prominent (Pe 2.5).	Styloniscus sp. 5

B7a	Animal white (Gm 2.2). Pereonites tuberculate and with a row of tubercles parallel with, and close to, the posterior margin of each pereonite (Pe 1.4).	Styloniscus sp. 6
B7b	Animal not white (Gm 2 3). Pereonites bumpy (Pe 1.5) or tuberculate sometimes with a row of tubercles parallel and close to the posterior margin of each pereonite (Pe 1.6).	Styloniscus sp. 7

3.5.3. PART C. PLATYARTHRIDAE AND BATHYTROPIDAE (5 TAXA)

C1a	Animal with brownish colouring (Gm 2.4) and prominent eyes of more than 6 ocelli (He 4.4, He 4.5).	C3
C1b	Animal pale cream or white (Gm 2.5) with eyes of less than 6 ocelli (He 4.6).	C2

C2a	Head with sub-triangular lateral lobes (He 7.6). Pleonal epimera 3, 4 & 5 very thin and terminating in an acute point (Pl 1.2).	Platyarthridae sp. 1
C2b	Head with large rounded lateral lobes (He 7.5). Pleonal epimera 3, 4 & 5 broad and terminating in a blunt point (Pl 1.1).	Platyarthridae sp. 2

C3a	Animal large (~7 mm long), flat and wide (Gm 4.3). Dorsal surface without dense scale-setae (Pe 1.7). Found only at Porongurup Range.	Australoniscus springetti
C3b	Animal smaller (max length 5 mm) less flat and wide (Gm 4.4, Gm 4.5). Dorsal surface with fine scale-setae (Pe 1.8).	C4

C4a	Animal 2 to 3 times long as broad (Gm 4.4).	Platyarthridae sp. 3
C4b	Animal 4 to 5 times long as broad (Gm 4.5).	Platyarthridae sp. 4

3.5.4. PART D. ONISCIDAE (4 TAXA)

D1a	Central frontal part of the head flat (He 6.3). Pereonites with large and well-defined tubercles (Pe 1.9).	Hanoniscus monodi
D1b	Central frontal part of the head rounded (He 6.4) or pointed (He 6.5, He 6.6). Pereonites with very small tubercles (Pe 1.11), bumpy (Pe 1.10) or with fine setae (Pe 1.12).	D2

D2a	Central frontal part of the head pointed (He 6.5). Pereonites irregularly bumpy (Pe1.10). Carpus of pereopod 1 of male densely setose (Pe 17.3).	Hanoniscus nicholisi
D2b	Central frontal part of the head rounded (He 6.4) or pointed (He 6.6). Pereonites with extremely fine tuberculation (Pe1.11) or setae (Pe 1.12). Carpus of pereopod 1 of male sparsely setose (Pe 17.4).	D3

D3a	Animal dark brown with lighter coloured patches (Gm 2.6). Central front part of head rounded (He 6.4). Pereonites with fine tubercles on dorsal surface (Pe 1.11).	Hanoniscus tuberculatus
D3b	Animal light brown or cream coloured with brown patches (Gm 2.7). Central front part of head pointed (He 6.6). Pereonites with fine setae on dorsal surface (Pe 1.12).	Hanoniscus sp. nov

3.5.5. PART E. PHILOSCIIDAE (5 TAXA)

E1a	Pereonites densely setose (Pe 1.13).	Philosciidae sp. 1
E1b	Pereonites not densely setose (Pe 1.14).	E2

E2a	Animal small (less than 7 mm long) and approximately 4 times as long as broad (Gm 4.6) with very pale colouring. Found in salt water, or possibly freshwater, or in a littoral situation.	Philosciidae sp. 2
E2b	Animal large (longer than 7 mm) not more than 3 times as long as broad (Gm 4.7, Gm 4 8) with strong colouring (Gm 2 8, Gm 2.9) and of terrestrial origin.	E3

E3a	Pleonal epimera 3, 4 & 5 extended creating a stepped outline on lateral margin of pleonites in dorsal view (Pl 1.4).	Eurygastor sp. nov.
E3b	Pleonal epimera 3, 4 & 5 truncate. Lateral margin of pleonites smooth in dorsal view (Pl 1.4).	E4

E4a	Animal about 3 times as long as broad (Gm 4.7). Base colouring of brown with cream markings (Gm 2 8). Pereonal epimera brown coloured with cream patches on each pereonite parallel to the lateral border of each epimeron (Pe 5.1). Pleopod exopodites of female rounded and usually of a single colour (Pl 2.2).	Laevophiloscia sp. 1
E4b	Animal about 2 times as long as broad (Gm 4 8). Base colouring of cream with brown patterning (Gm 2.9). Pereonal epimera cream coloured (Pe 7.1). Pleopod exopodites of female pointed and with distinct markings (Pl 2.3).	Laevophiloscia sp. 2

3.5.6. PART F. ARMADILLIDAE (24 TAXA)

F1a	Maximum length not usually more than 5 mm. Inner lobe of pereonal epimeron 1 very long, much longer than posterior corner of epimera 1 in lateral view (Pe 12.3). Inner lobe of pereonal epimeron 2 large, rounded and projecting backward much larger than outer lobe which is pointed (Pe 14.1). Telson very short and wide (Pl 7 5) with distal margin the shortest point.	F2
F1b	Maximum length usually more than 5 mm. Inner lobe of pereonal epimeron 1 just larger than, equal to or shorter than (not visible) posterior corner of epimera 1 in lateral view (Pe 12.4 – Pe 12.12). Inner lobe of epimeron 2 small and never visible in lateral view (Pe 14.2). Telson hourglass shaped with midpoint narrower than distal margin (Pl 7.6 - Pl 7.11).	F9

F2a	Frontal ridge with flattened appearance (He 9.1) not produced to point in centre (He 9.2). No distinct bumps on pereonites at junction with epimera. Without bumps on dorsal surface of pereonite 6 & 7.	Pseudodiploexochus sp. 1
F2b	Frontal ridge sometimes with flattened appearance but usually forming an obtuse triangular point in the centre (He 9.2). Pereonites with bumps or spines at junction with pereonal epimera forming a row parallel to lateral margin (Pe 5.2). Always with spines or well-defined bumps on dorsal surface of pereonite 6 & 7.	F3

F3a	Pereonites with long spines (Pe 1.15). Pereonal epimera with or without terminal spines.	F4
F3b	Pereonites with short spines or bumps (Pe 1.16, Pe 1.17, Pe 1.18). Pereonal epimera always without terminal spines.	F6

F4a	Pleonal epimera with terminal spines (Pl 1.5).	F5
F4b	Pleonal epimera without terminal spines (Pl 1.6).	Pseudolaureola sp. 1

F5a	Centre of frontal ridge with 2 prominent frontal projections (He 9.3).	Pseudolaureola sp. 2
F5b	Centre of frontal ridge without 2 prominent frontal projections (He 9.4)	Pseudolaureola wilsmorei

F6a	Pereonites with prominent spherical bumps producing fine setae (Pe 1.16). Restricted to karri forest	Pseudolaureola sp. 3
F6b	Dorsal surface with short spines (Pe 1.17) or non-spherical bumps (Pe 1.18).	F7

F7a	Pereonites with short spines (Pe 1.17) Row of spines nearest to the lateral border of the pereonal epimera widened and paddle shaped (Pe 5.3) Head with very short spines	Pseudolaureola sp. 4
F7b	Pereonites with very short spines or bumps (Pe 1 18). Row of spines nearest to the lateral border of the pereonal epimera not paddle shaped.	F8

F8a	Frontal ridge forming an obtuse triangular point in the centre (He 9.2). Spines very short and broad and definite spines present on pereonite 6 & 7 (Pe 3.1) and row nearest to lateral border of pereonal epimera slightly widened. Head without definite spines but with very prominent bumps (He 5 4).	Pseudolaureola sp. 5
F8b	Frontal ridge with flattened appearance. Pereonites with bumps most prominent on dorsal surface of pereonites 6 & 7 (Pe 3.2). Head slightly bumpy.	Pseudodiploexochus sp. 2
F8c	Frontal ridge with flattened appearance Pereonites with bumps most prominent on dorsal surface of pereonite 6 & 7 terminating in fine setae (Pe 1.19). Head slightly bumpy.	Pseudodiploexochus sp 3

F9a	Pereonal epimeron 1 with ventral groove (sulcus marginali) (Pe 9 1, Pe 9.2)	F10
F9b	Pereonal epimeron 1 without ventral groove (sulcus marginali) (e g Pe 9.3, Pe 9.4)	F12

F10a	Animal pale in colour, almost white (Gm 2.10) Eye small (< 6 ommatidia) (He 4.7). Posterior margin of pereonal epimeron 1 almost straight (Pe 10.3)	Spherillo sp. 1
F10b	Animal not pale in colour. Eye of moderately (He 4 8) or well developed (He 4.9). Posterior margin of pereonal epimeron 1 angled backwards (Pe 10.4).	F11

F11a	Pereonal epimeron 1 with ventral groove approximately the same width along entire ventral surface (Pe 9.1) Pereonites generally bumpy (highly variable character state) (Pe 1 20). Posterior margin of pereonal epimeron 7 with posterior kink (Pe 15.1). Pereonal epimeron 2 pointed (Pe 13.1).	Spherillo sp. 2
F11b	Pereonal epimeron 1 with ventral groove (sulcus marginali) narrowing anteriorly (Pe 9.2). Pereonites smooth. Posterior margin of pereonal epimeron 7 without postenor kink (Pe 15.2). Pereonal epimeron 2 rounded (Pe 13 2).	Spherillo sp 3

F12a	Inner lobe of pereonal epimeron 1 attached to or produced from lateral border of epimeron (Pe 9.1, Pe 9.2, Pe 9.3) and visible in lateral view (Pe 12.4, Pe 12.5, Pe 12.7, Pe 12.8, Pe 12.9, Pe 12.11, Pe 12.12).	F13
F12b	Inner lobe of pereonal epimeron 1 small and separated from lateral border of epimeron (Pe 9.4) and not visible in lateral view (Pe 12.6).	F20

F13a	All pereonal epimera strongly curved and rounded backwards, most evident in pereonal epimera 1-5 (Pe 6.1 Pe 6.2).	F14
F13b	All pereonal epimera angled backwards but not highly curved (Pe 6.3), angled slightly backwards or all mostly straight.	F15

F14a	Animal white/cream colour with highly curved epimera angled strongly backwards (Pe 6.1). Pereonite 1 with very distinctive sculptured pattern on dorsal surface (Pe 4.1) more pronounced in juveniles (Pe 4.1 juv.).	Acanthodillo flavus
F14b	Animal brownish coloured with moderately curved epimera angled strongly backwards (Pe 6.2). Pereonite 1 very bumpy but lacking distinctive sculptured pattern (Pe 4.2).	Acanthodillo sp. 1

F15a	Pereonal epimeron 2 terminating in a point (Pe 13.3).	Acanthodillo sp. 2
F15b	Pereonal epimeron 2 truncate (Pe 13.4) or rounded (Pe 13.5) but not terminating in a point.	F16

F16a	First pleonal epimeron angled backwards (Pe 10.6 - Pe 10.8) with inner lobe visible in lateral view (Pe 12.9 - Pe 12.12). Eyes moderately or well-developed (He 4.10)	F18
F16b	First pleonal epimeron nearly straight (Pe 10.5) with a truncate posterior corner of epimera (Pe 12.7 - Pe 12 8) and smaller inner lobe still visible in lateral view. Eyes small (He 4.11).	F17

F17a	Pereonites covered in fine setae (Pe 1.23). Outer lobe of pereonal epimeron 1 with rounded incision (Pe 12.7). Without two well defined bumps on head.	Acanthodillo sp 3
F17b	Pereonites without fine setae but with scaly appearance and well defined bumps arranged in longitudinal rows (Pe 1.24). Two well defined bumps on head, one behind each eye (He 5.5). Frontal ridge projecting slightly above vertex of head (He 10.1) and sub-triangular in shape (He 9.5).	Acanthodillo sp. 4

F18a	Eyes very well developed (He 4.10). Outer lobe of pereonal epimera 1 truncate (Pe 12.9). Pereonal epimeron 7 with kink in posterior margin (Pe 15.3). Uropod protopodites short and not tapering distally (Pl 6 4). Telson barely wider at distal margin than at midpoint (Pl 7.10-11).	F19
F18b	Eyes only moderately developed (He 4.11). Pereonal epimeron angled backward (Pe 10.6) and rounded (Pe 12.10). Pereonal epimeron 7 without kink in posterior margin (Pe 15 4). Uropod protopodites longer and tapering distally (Pl 6.5). Telson wider at distal margin than at midpoint (Pl 7.9)	Acanthodillo sp. 5

F19a	Frontal ridge flattened (He 10.3). Dorsal surface of pereonite 1 smooth. Posterior margin of pereonal epimeron 1 angled moderately backward (Pe 10.7). Inner lobe of pereonal epimeron 1 clearly visible beyond posterior corner of epimera in lateral view (Pe 12.11). Telson as Pe 7.10. Animal of small/moderate size. Animal orange-brown in colour.	Spherillo sp. 4
F19b	Frontal ridge well-defined and raised slightly from dorsal surface of head (He 10.4). Distinct bumps and depressions usually present on dorsal surface of pereonite 1 (Pe 4.3). Posterior margin of pereonal epimeron 1 angled strongly backward (Pe 10.8). Inner lobe of pereonal epimeron 1 just visible beyond posterior corner of epimera in lateral view (Pe 12.12). Telson as Pe 7.11. Animal of moderate/large size with a purple-brown or brown and cream colour	Spherillo sp. 5

F20a	Pereonites with well defined (Pe 1.21) or moderately (Pe 1.22) raised bumps. Telson with two bumps near anterior border (Pl 7.7).	F21
F20b	Pereonites smooth. Telson without two bumps near anterior border.	F22

F21a	Pereonites densely tuberculate with transverse row of tubercles on the posterior margin of each pereonite (Pe 1.21).	Cubaris sp. 1
F21b	Pereonites with small bumps in longitudinal rows but without transverse row of tubercles on the posterior edge of pereonites (Pe 1.22).	Cubaris sp. 2

F22a	Animal cream and pale brown in colour (Gm 2.11). Frontal ridge curved and projecting well above vertex of head. Clypeal lobes inconspicuous. Pereonal epimeron 2 rounded (Pe 13.5). Uropods short and not tapering (Pl 6.2). Telson barely wider at distal margin than at midpoint (Pl 7.6).	Cubaris sp.3
F22b	Animal not cream and pale brown in colour. Frontal ridge almost straight (He 9.6) and projecting well above vertex of head (He 10.2). Clypeal lobes very long (He 11.1). Pereonal epimeron 2 truncate (Pe 13.4). Uropods long and tapering (Pl 6.3). Telson much wider at distal margin than midpoint and with rounded appearance (Pl 7.8).	Cubaris sp. 4

3.5.7. PART G. ARMADILLIDAE: BUDDELUNDIA (14 TAXA)

G1a	Frontal ridge flattened with secondary frontal development behind primary frontal line (He 8.1, He 8.2). Pereonite 1 with furrow parallel to lateral margin (sulcus arcuatus) (Pe 11.1, Pe 11.2, Pe 11.3) or with very bumpy pereonites (Pe 1.25).	G2
G1b	Frontal ridge formed by single well-defined line with no secondary frontal development behind primary frontal line. Pereonite 1 without deep furrow parallel to lateral margin (sulcus arcuatus) (Pe 11.3). Dorsal surface always smooth except for some shallow bumps on first pereonite (Pe 4.4).	G7

G2a	Secondary development of frontal ridge continuous along its entire length (He 8 1).	G3
G2b	Secondary development of frontal ridge confined to each end (He 8 2).	G6

G3a	Clypeal lobes long and sharply pointed (He 11.2). Posterior margin of pereonal epimeron 1 angled backwards (Pe 10.9).	G4
G3b	Clypeal lobes slightly pointed, subrectangular or rounded (He 11.3). Pereonal epimeron 1 nearly straight (Pe 10.10, Pe 10.11).	G5

G4a	Inner lobe of pereonal epimeron 1 shorter than posterior corner of epimera, appearing truncate in lateral view (Pe 12.13).	Buddelundia inaequalis
G4b	Inner lobe of pereonal epimeron 1 equal to or longer than posterior corner of epimera (Pe 12.14).	Buddelundia cinerascens

G5a	Dorsal surface of pereonites bumpy (Pe 1.25). Pereonal epimeron 1 without a furrow parallel to lateral margin (sulcus arcuatus) (Pe 11.3).	Buddelundia sp. 1
G5b	Dorsal surface of pereonites smooth. Pereonal epimeron 1 with a deep and narrow furrow parallel to lateral margin (sulcus arcuatus) (Pe 11.1).	Buddelundia sp. 2

G6a	Pereonal epimeron 1 with a deep and wide furrow parallel to lateral margin (sulcus arcuatus) (Pe 11.2). Inner lobe of pereonal epimeron 1 longer than posterior corner of epimera in lateral view (Pe 12.15)	Buddelundia opaca
G6b	Pereonal epimeron 1 without furrow parallel to lateral margin (sulcus arcuatus) (Pe 11.3). Inner lobe of pereonal epimeron 1 slightly shorter or equal to posterior corner of epimera in lateral view (Pe 12.16).	Buddelundia sp. 3

G7a	Posterior margin of pereonal epimeron 1 curved backward and rounded (Pe 10.12).	G8
G7b	Posterior margin of pereonal epimeron 1 angled slightly backward or nearly straight (Pe 10.13, Pe 10.14).	G10

G8a	Frontal ridge generally in smooth arc (He 9.8). Head with 2 large and long bumps between eyes and frontal ridge (He 5.6). Pereonite 1 with shallow bumps (Pe 4.4). Telson short and barely wider at distal border than at narrowest point which is near to distal border (Pl 7.12).	Buddelundia sp. 4
G8b	Frontal ridge straighter, forming less of an arc and depressed to some extent between the eyes and central part (He 9.9) or nearly straight and raised in the centre (He 9.10). Pereonite 1 smooth. Telson elongate, rounded and wider at distal border than at narrowest point which is approximately the midpoint (Pl 7 13, Pl 7.14).	G9

G9a	Animal dark brown with cream patches (Gm 2.12). Frontal ridge moderately straight and raised and rounded in centre (He 9.9). Telson slightly elongate and rounded (Pl 7.13).	Buddelundia sp. 5
G9b	Animal cream with brown patches (Gm 2.13). Frontal ridge in smooth arc and less straight at each end (He 9.10). Telson greatly elongate and rounded (Pl 7.14).	Buddelundia sp. 6

G10a	Animal light coloured, usually with a well defined broad cream coloured band along lateral margins of animal (Gm 2 14). Pereonal epimeron 2 slightly pointed on anterior lateral border (Pe 13.6). Telson short with little difference in width at narrowest point and distal margin (Pl 7.15).	Buddelundia sp. 7
G10b	Animal of uniform colouring or blotchy appearance (Gm 2 15) without cream coloured band along lateral margin. Pereonal epimeron 2 not slightly pointed on anterior lateral border. Telson wider at distal margin than narrowest point (Pl 7.15).	G11

G11a	Outer lobe of pereonal epimeron 1 produced with a kink at junction with thickened lateral margin of epimeron 1 (Pe 12.17). Pereonal epimeron 2 rounded (Pe 13.7).	G12
G11b	Outer lobe of pereonal epimeron 1 produced without kink at thickened lateral margin of epimeron (Pe 12.18). Pereonal epimeron 2 sub-rectangular forming a point (Pe 13.8).	G13

G12a	Animal of blotchy appearance (Gm 2.15) with pereopods of two colours (Pe 16.1). Head with bumps behind frontal ridge (He 5.7). Pereonite 1 sometimes with large shallow bumps. Posterior margin of pereonal epimeron 1 angled slightly backwards (Pe 10.13).	Buddelundia nigripes
G12b	Animal of a uniform grey brown colour with peraopods of one colour (Pe 16.2). Head and pereonites uniformly smooth. Posterior margin of pereonal epimeron 1 straight or nearly so (Pe 10.14).	Buddelundia nitidissima

G13a	Animal not larger than 6 mm with white spots on each pereonite at junction with each epimeron (Pe 5.4).	Buddelundia albomaculata
G13b	Animal larger than 6 mm without white spots on each pereonite at junction with each epimeron	Buddelundia sp. 8

3.6. CHARACTER STATES USED IN THE KEY

3.6.1. GENERAL MORPHOLOGY CHARACTERS

3.6.1.1. Gm 1 General morphology/conglobation

Plate 3.1. Character state Gm 1.

3.6.1.2. Gm 2 General morphology/colour

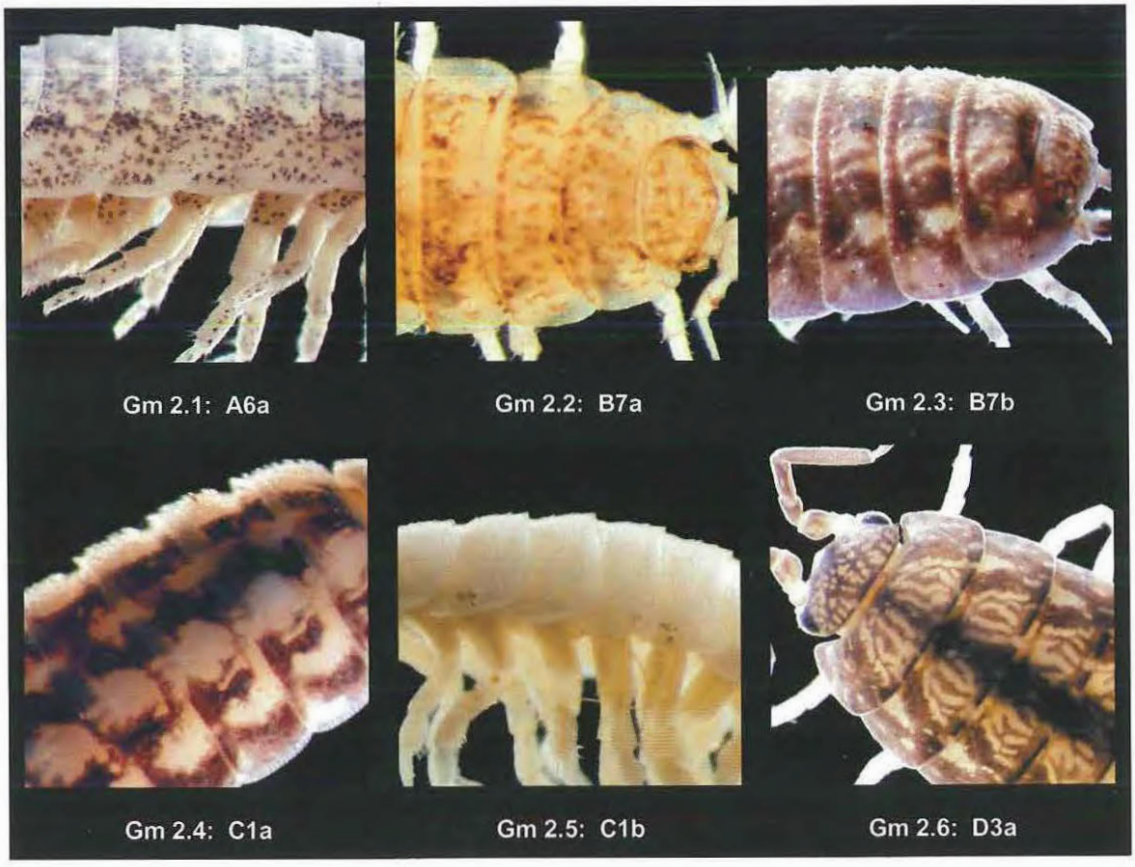


Plate 3.2. Character state Gm 2.

3.6.1.3. Gm 3 General morphology/body outline

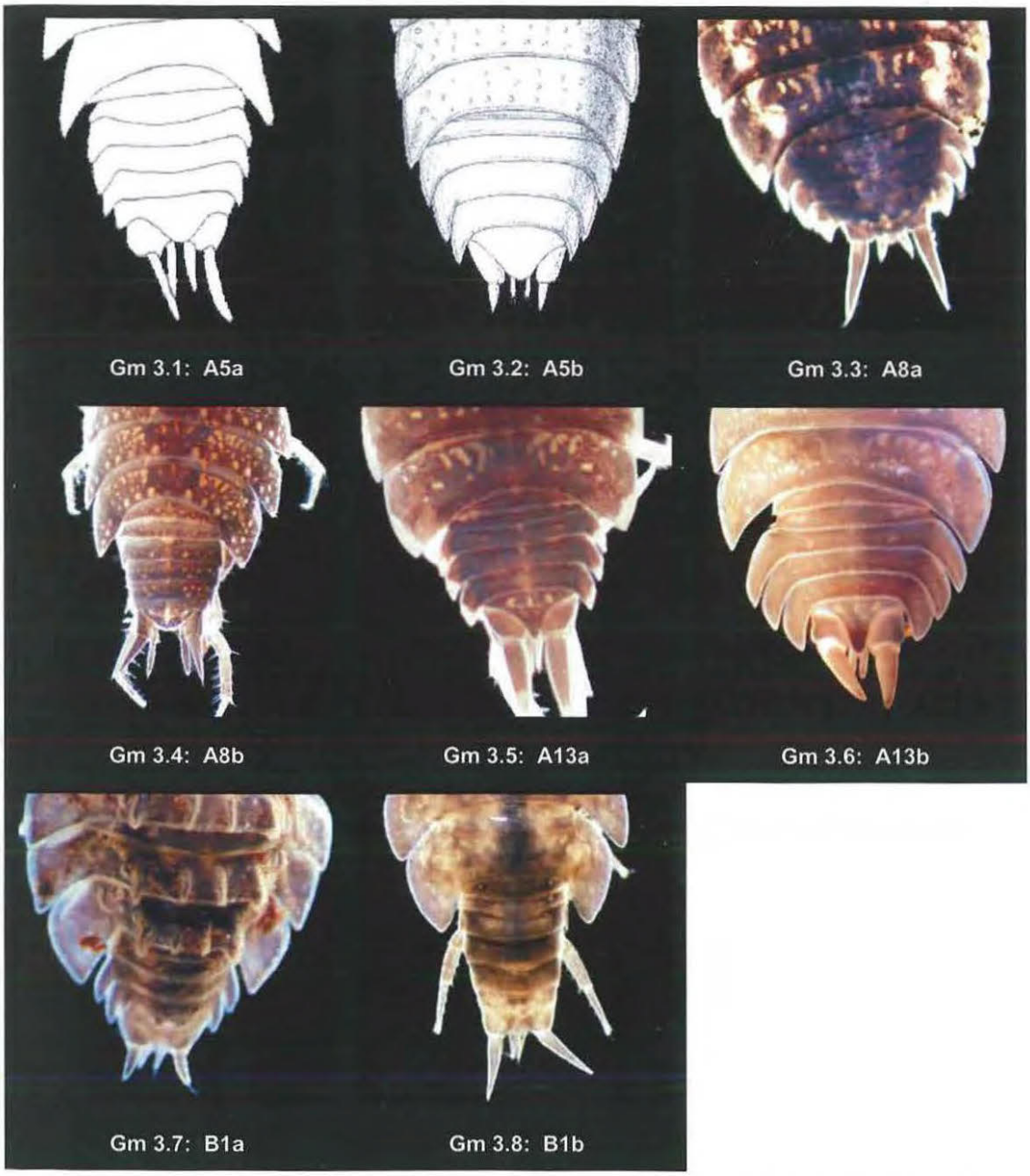


Plate 3.3. Character state Gm 3. Gm 3.1 adapted from Williams (1970, fig 1K) and Gm 3.2 adapted from Chilton (1915a, plate 39, fig.19).

3.6.1.4. Gm 4 General morphology/body shape

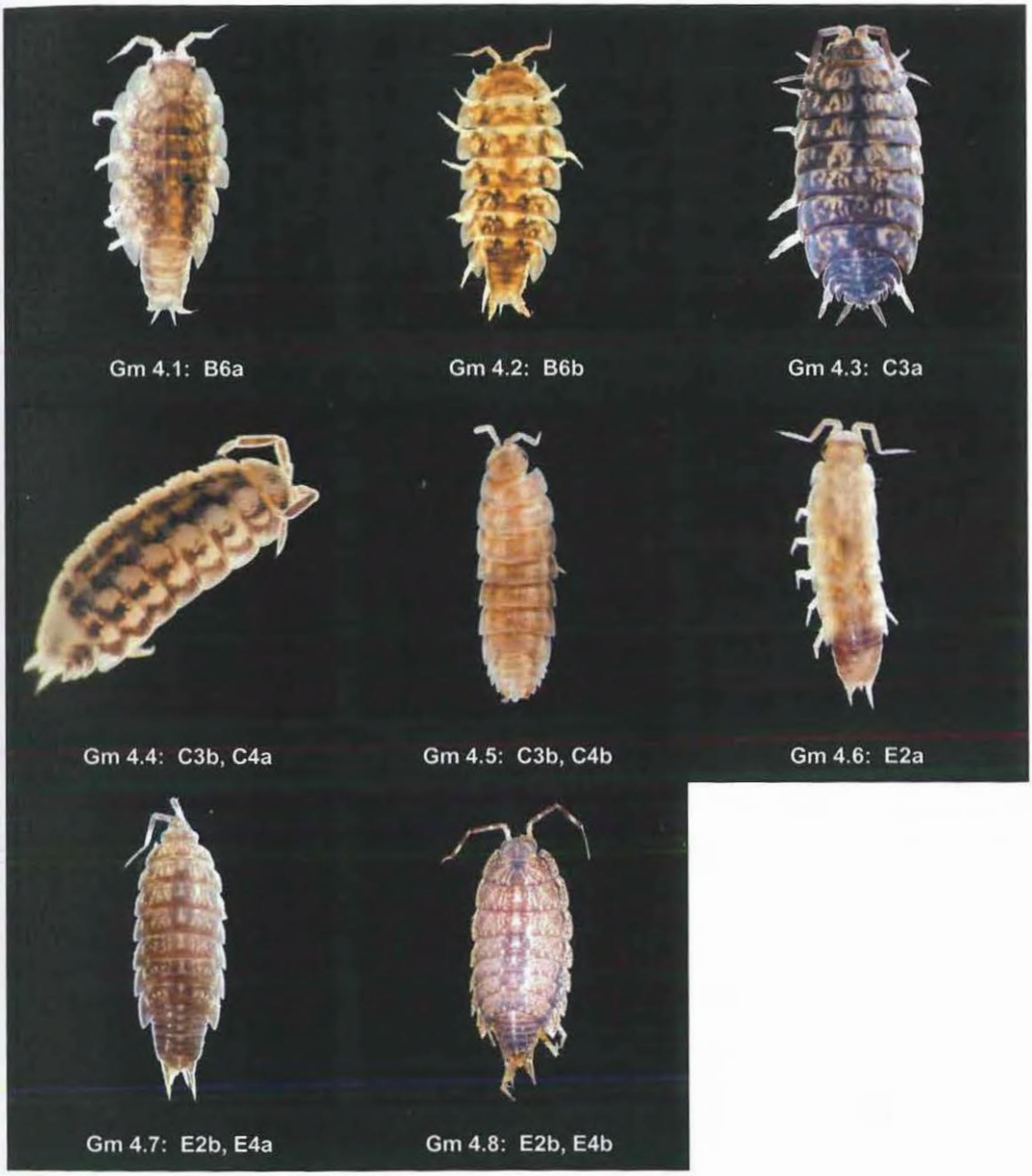


Plate 3.4. Character state Gm 4.

3.6.2. CHARACTERS OF THE HEAD

3.6.2.1. He 1 Head/antenna 2/flagellum/number of articles

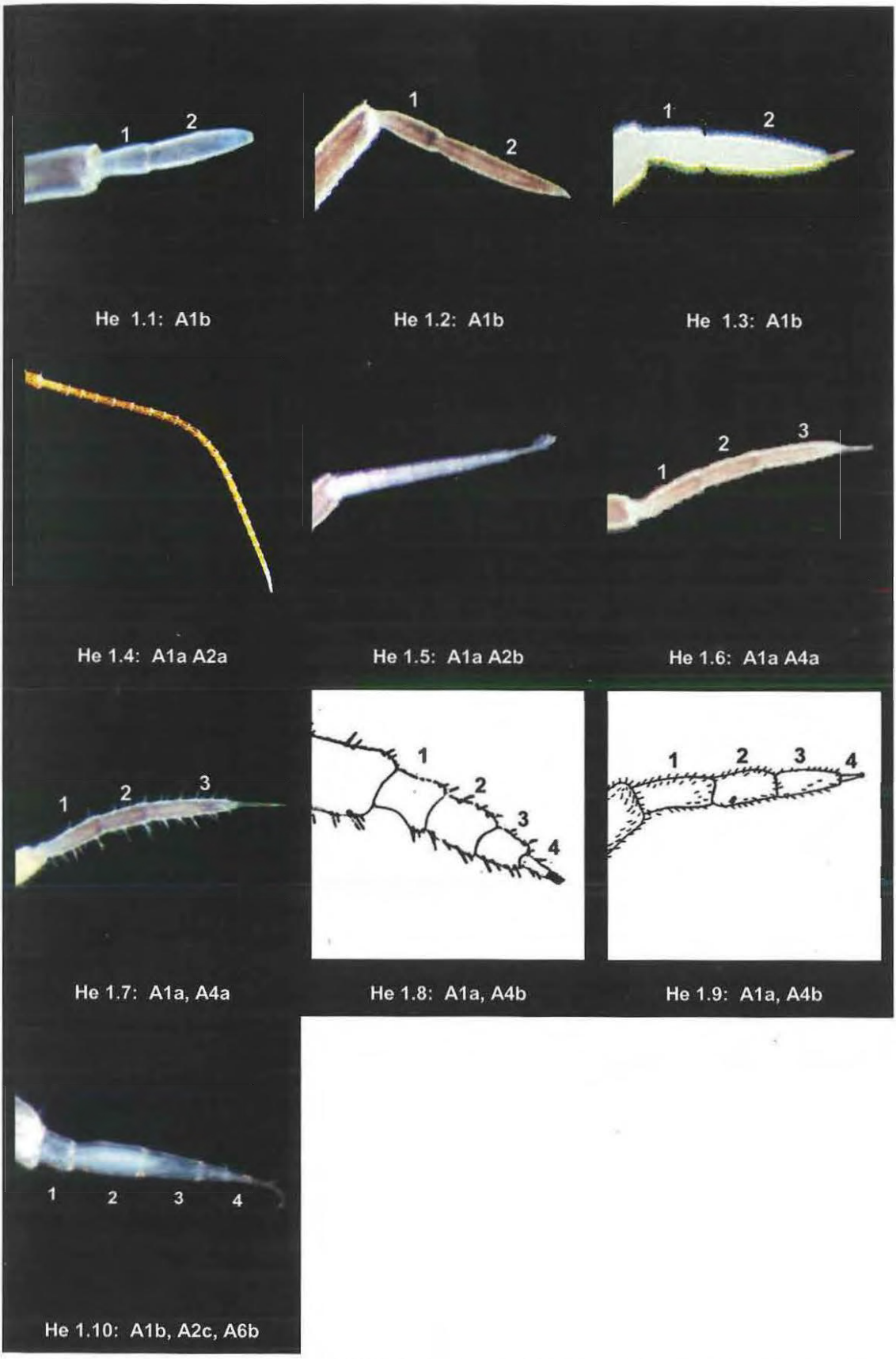


Plate 3.5. Character state He 1. He 1.8 adapted from Nicholls and Barnes (1926, plate 20, fig. 2) and He 1.9 adapted from Williams (1970, fig. 1C).

3.6.2.2. He 2 Head/antenna 2/relative length of articles

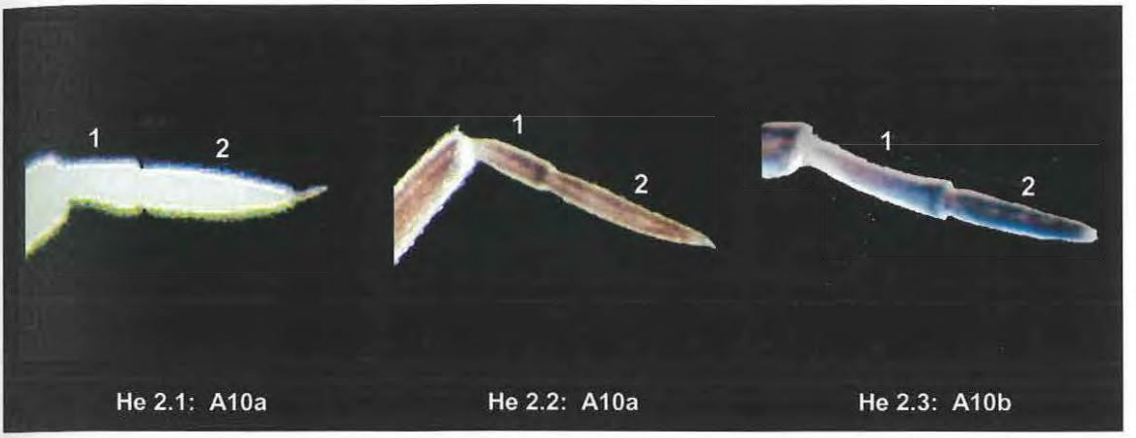


Plate 3.6. Character state He 2.

3.6.2.3. He 3 Head/antenna 2/peduncle/articles 4 and 5/shape

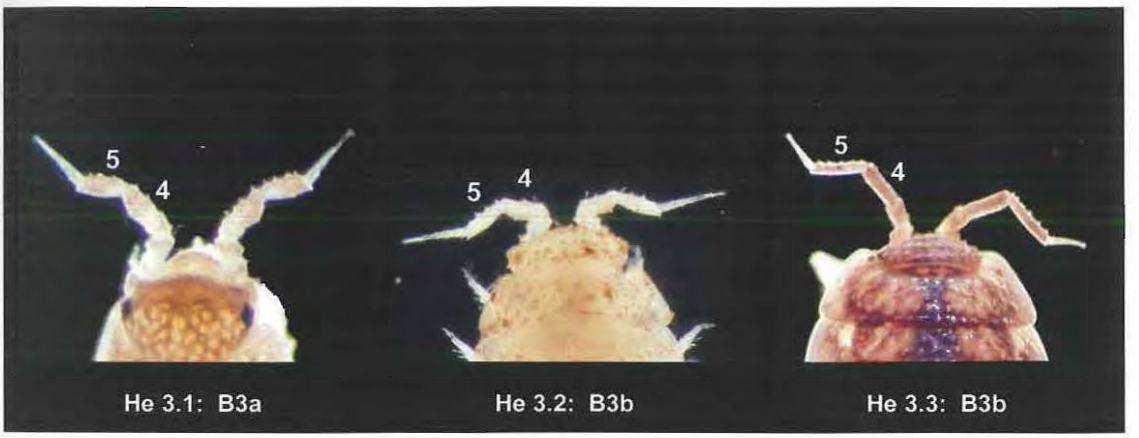


Plate 3.7. Character state He3.

3.6.2.4. He 4 Head/eye/size

Plate 3.8. Character state He 4.

3.6.2.5. He 5 Head/dorsal surface

Plate 3.9. Character state He 5.

3.6.2.6. He 6 Head/frontal lobe/shape

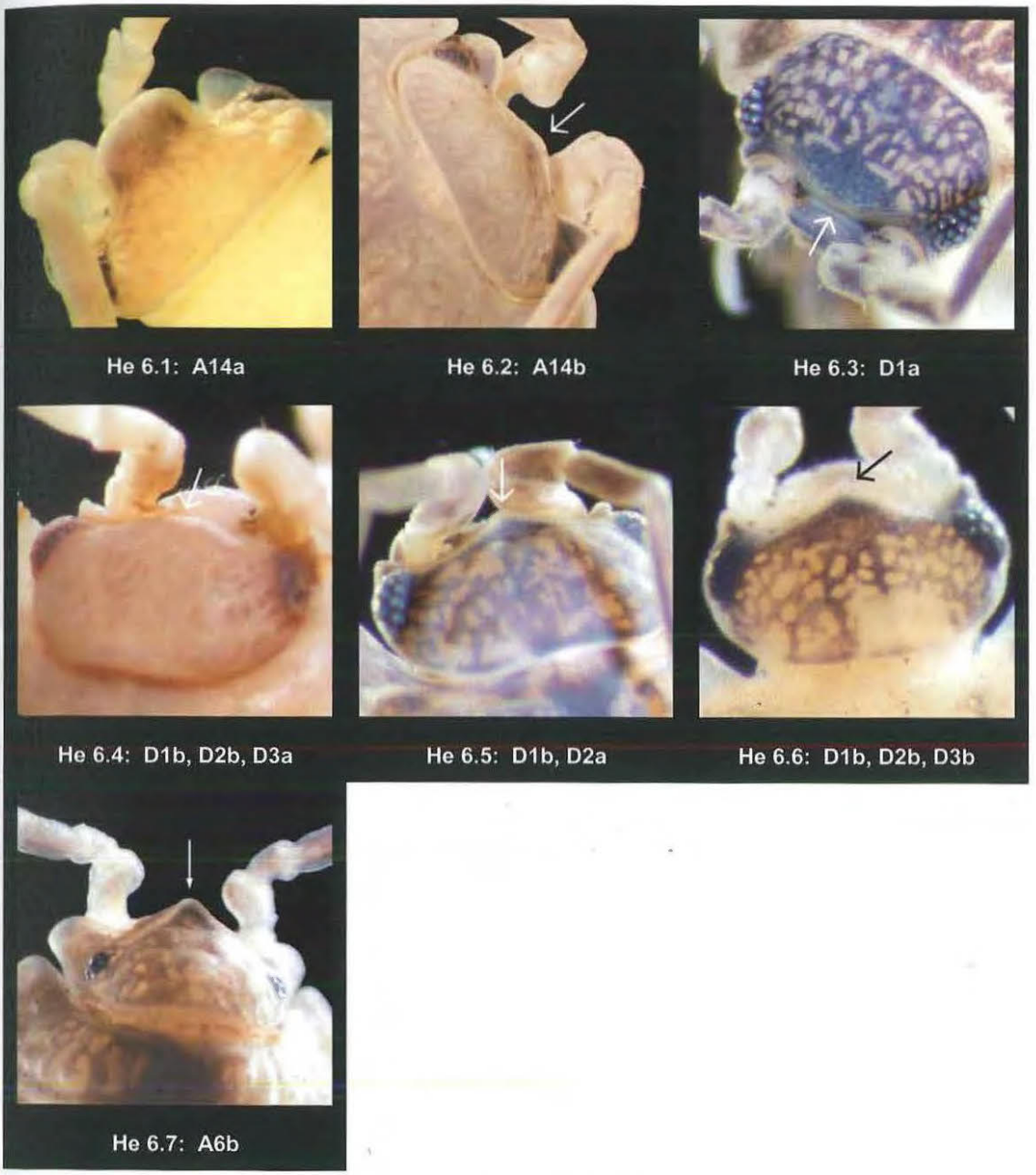


Plate 3.10. Character state He 6.

3.6.2.7. He 7 Head/lateral lobes/shape

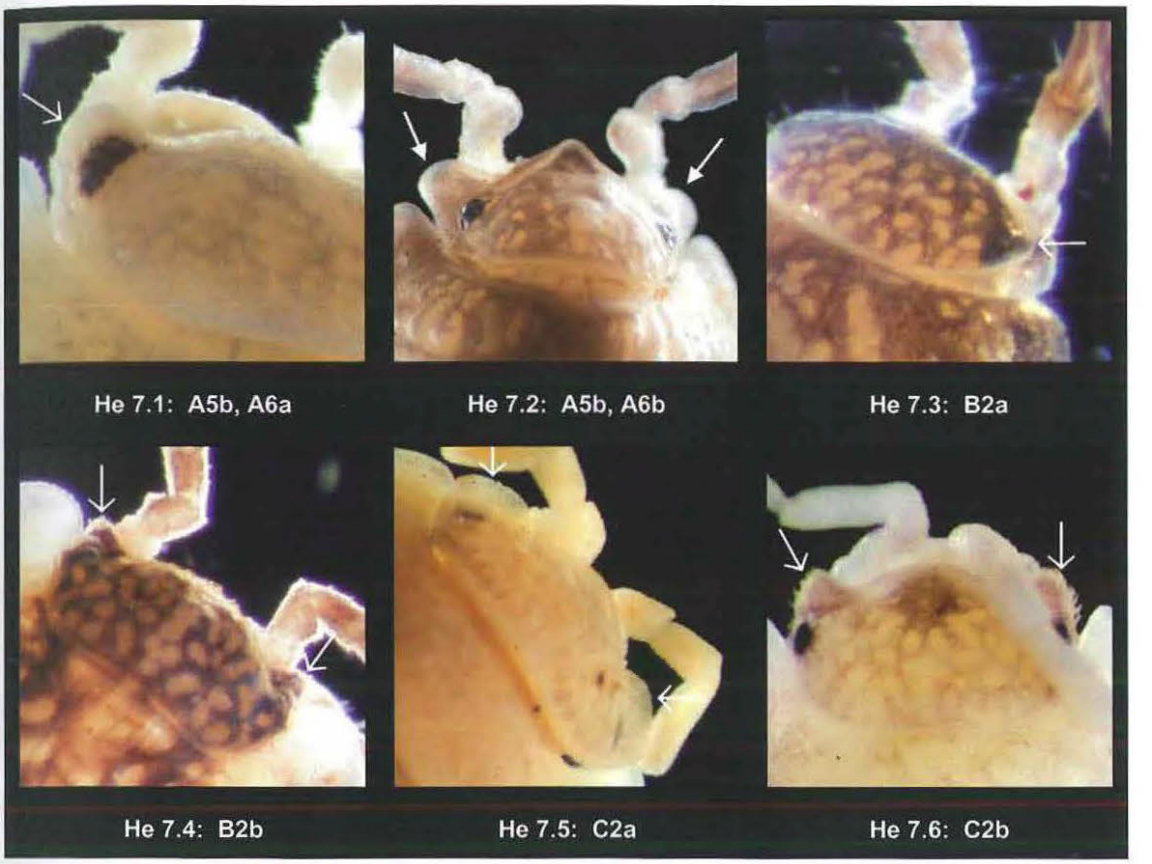


Plate 3.11. Character state He 7.

3.6.2.8. He 8 Head/frontal ridge/secondary development

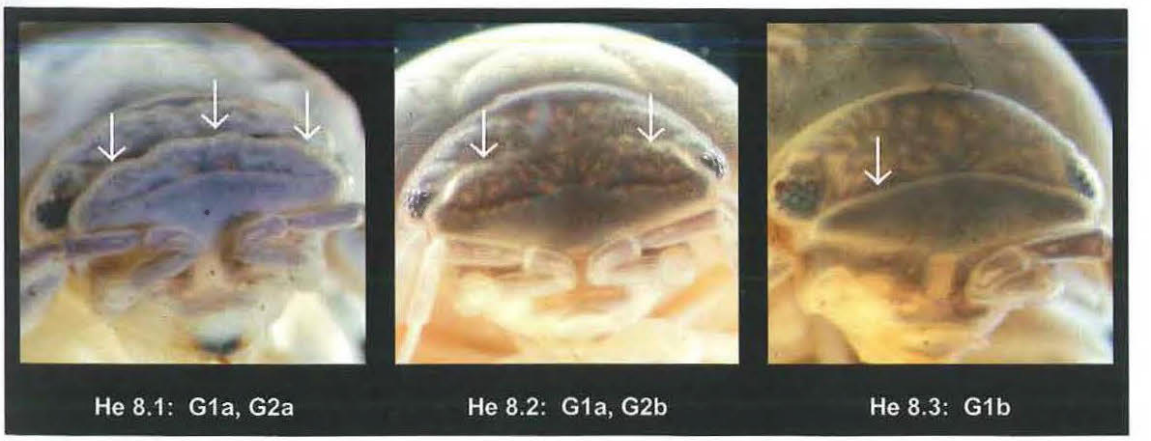


Plate 3.12. Character state He 8.

3.6.2.9. He 9 Head/frontal ridge/shape

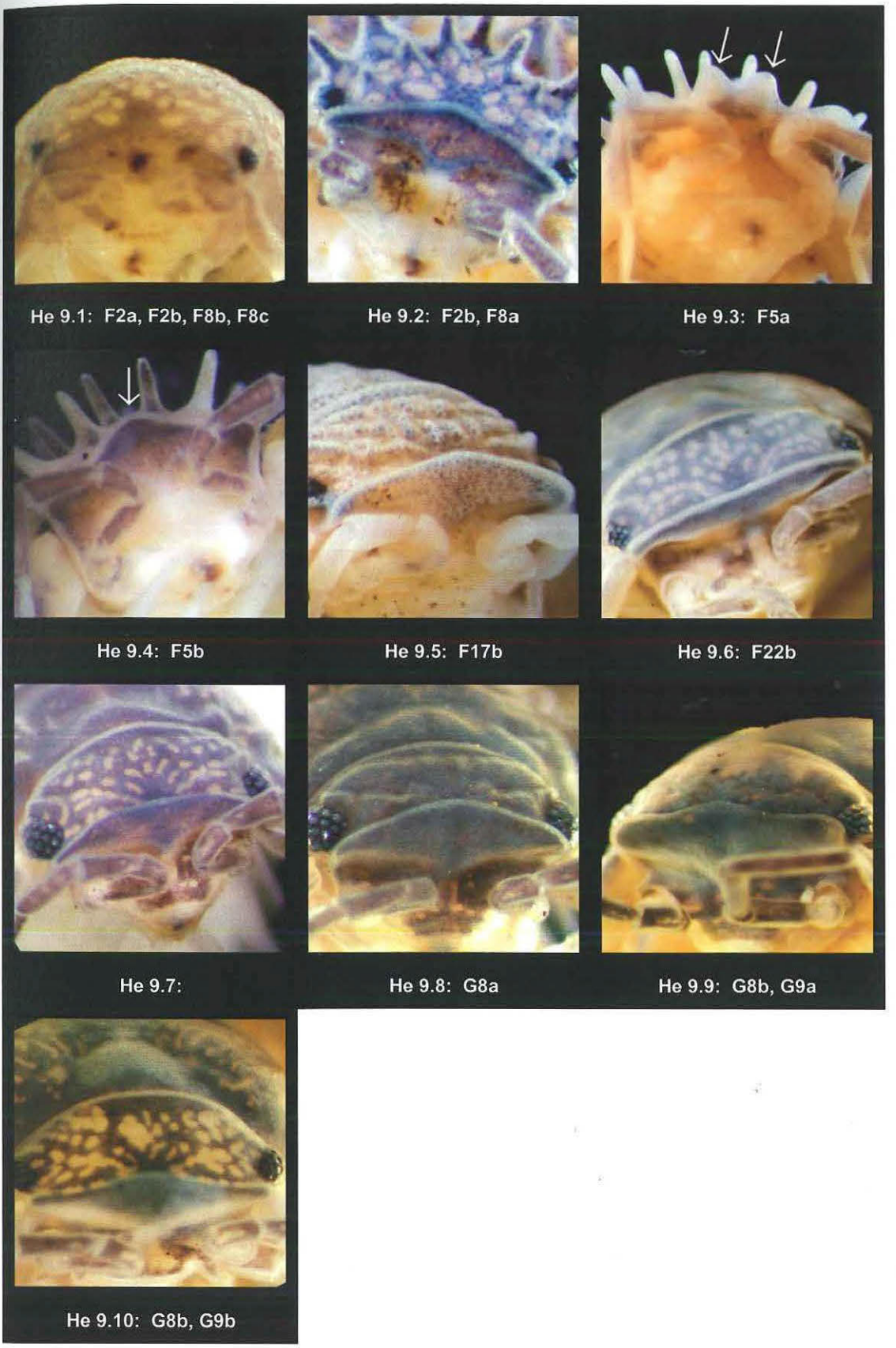


Plate 3.13. Character state He 9.

3.6.2.10. He 10 Head/frontal ridge/raised from vertex

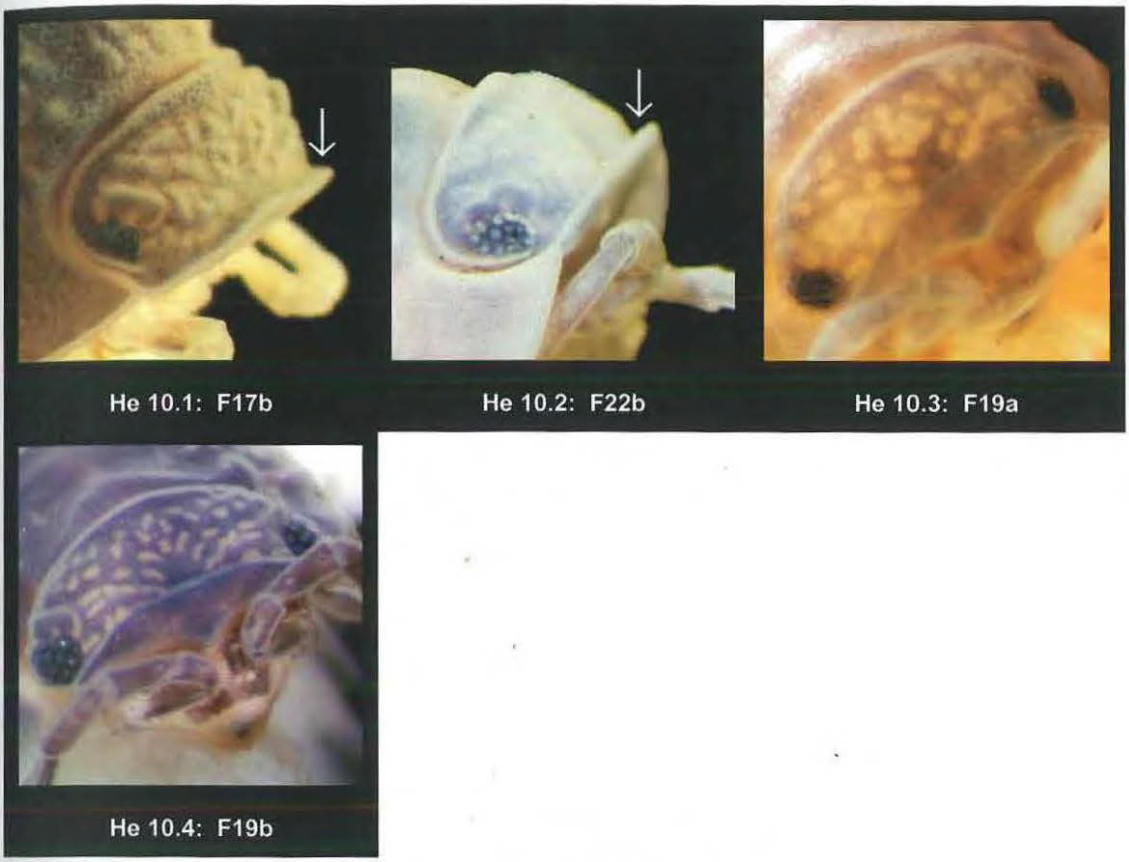


Plate 3.14. Character state He 10.

3.6.2.11. He 11 Head/clypeal lobes/shape

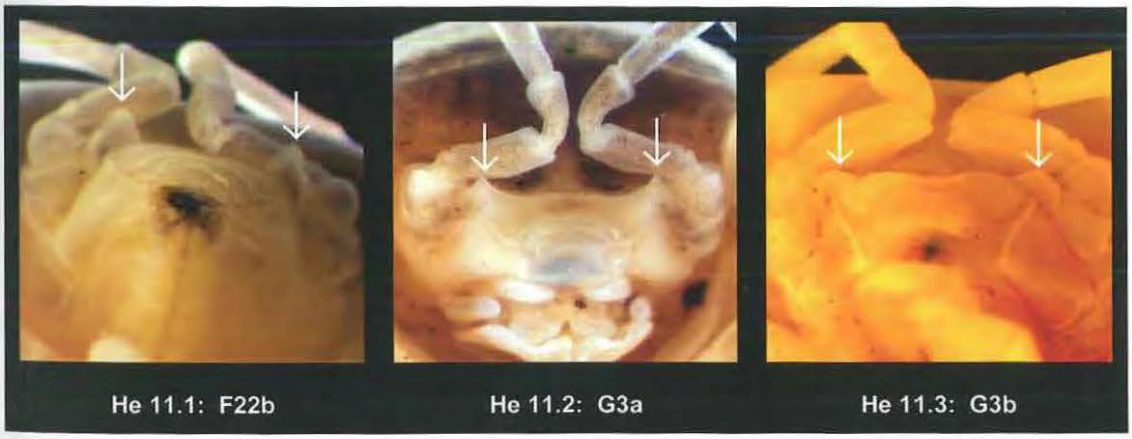


Plate 3.15. Character state He 11.

3.6.2.12. He 12 Head/antenna 2/length

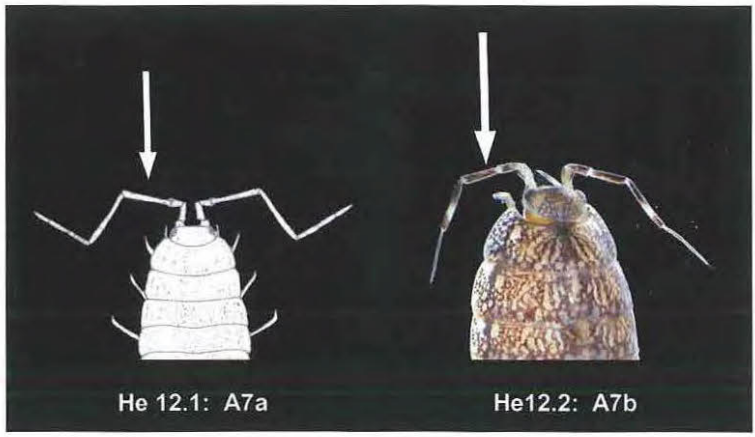
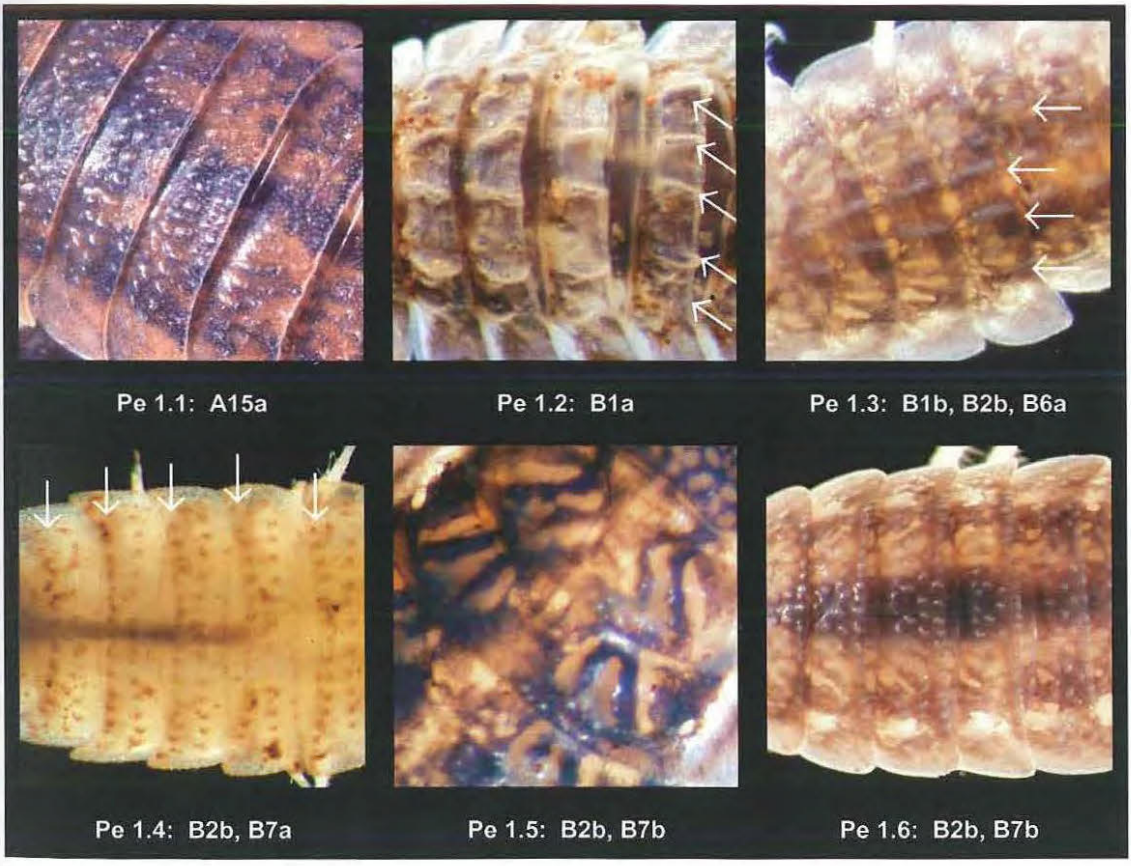


Plate 3.16. Character state He 12. Character state He 12.1 adapted from Hopkin (1991, fig. 16c

3.6.3. CHARACTERS OF THE PEREON

3.6.3.1. Pe 1 Pereon/pereonites/surface



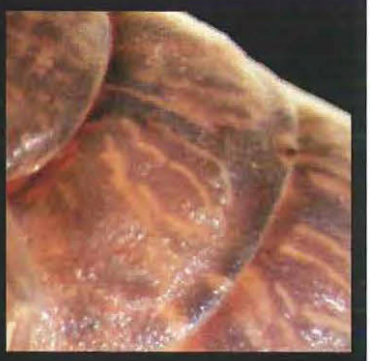
Pe 1.7: C3a

Pe 1.8: A10a, C3b

Pe 1.8: A10a, C3b

Pe 1.9: D1a

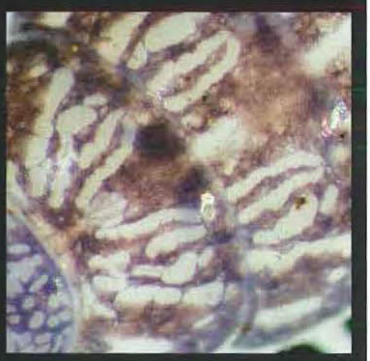
Pe 1.10: D1b, D2a



Pe 1.11: D1b, D2b, D3a

Pe 1.12: D1b, D2b, D3b

Pe 1.13: E1a



Pe 1.14: E1b

Pe 1.15: F3a

Pe 1.16: F3b, F6a

Pe 1.17: F3b, F6b, F7a

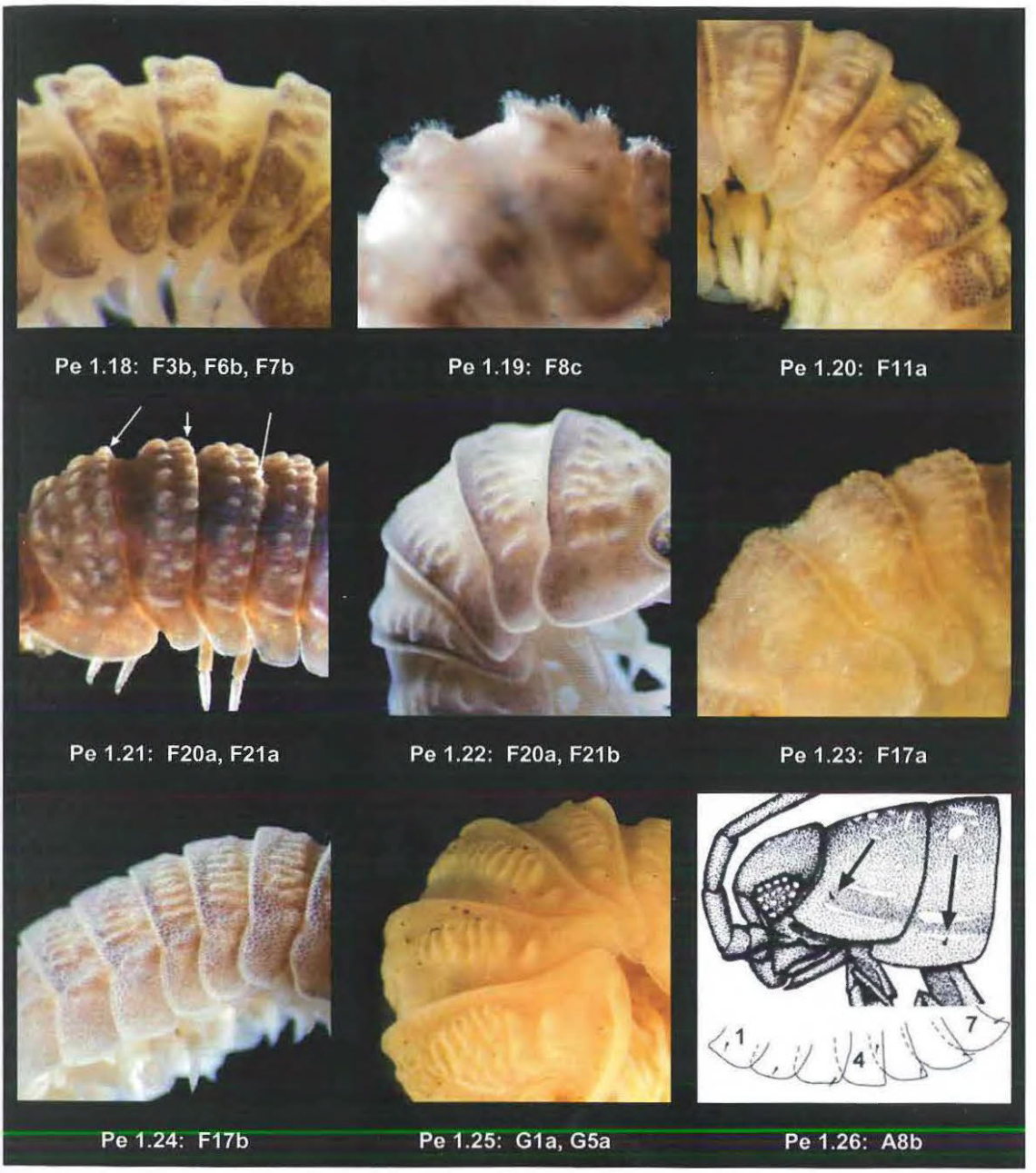


Plate 3.17. Character state Pe 1. (Pe 1.1 adapted from Hopkin (1991, front cover) and Character state Pe 1.26 adapted from Araujo and Leistikow (1999, Fig. 6).

3.6.3.2. Pe 2 Pereon/pereonites 1, 2 and 3/surface

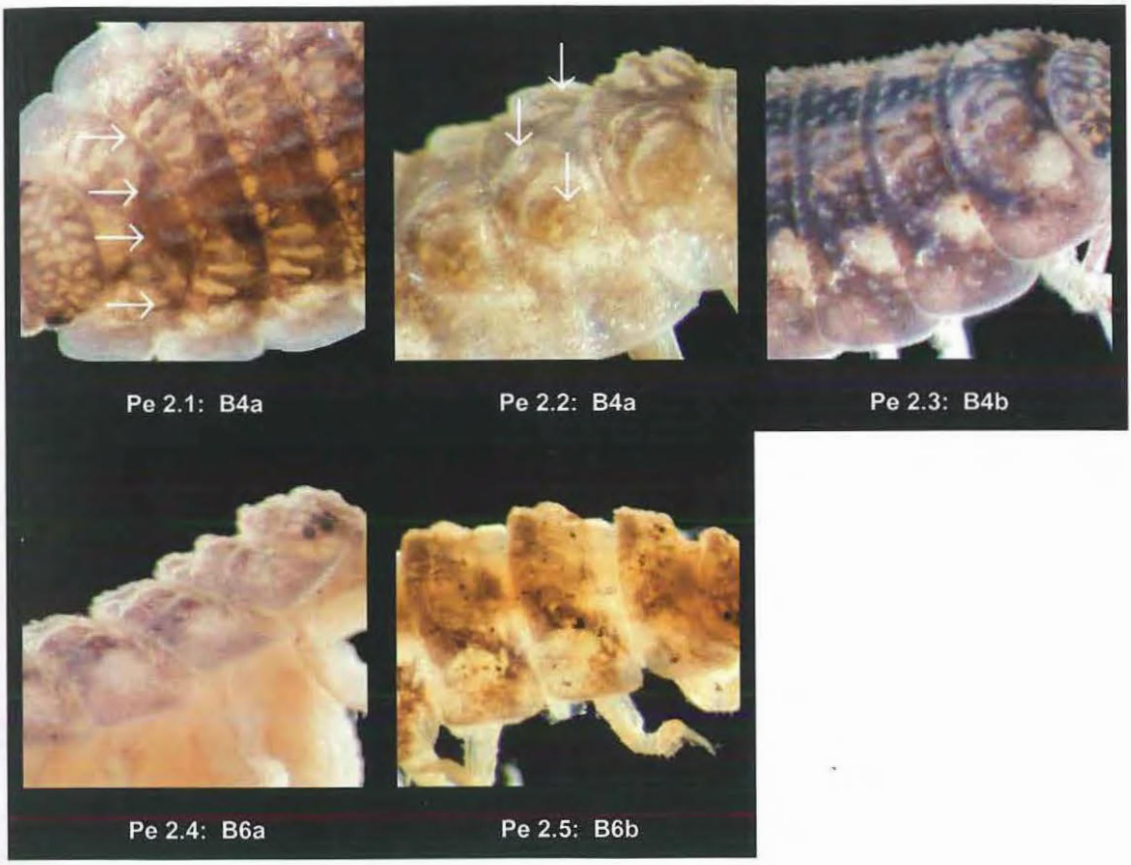


Plate 3.18. Character state Pe 2.

3.6.3.3. Pe 3 Pereon/pereonites 6 and 7/surface

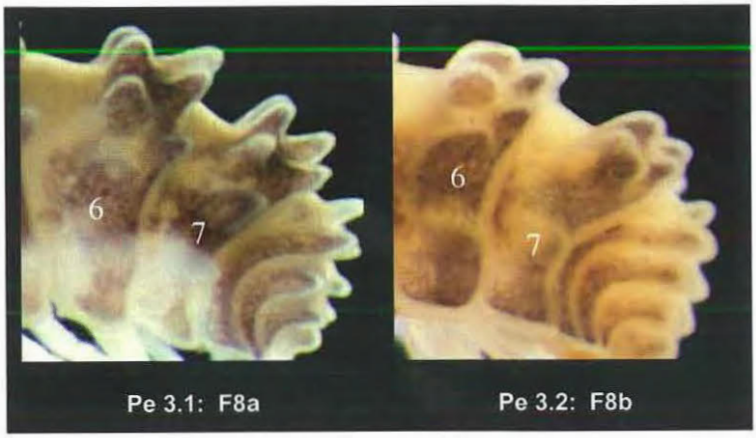


Plate 3.19. Character state Pe 3.

3.6.3.4. Pe 4 Pereon/pereonite 1/surface

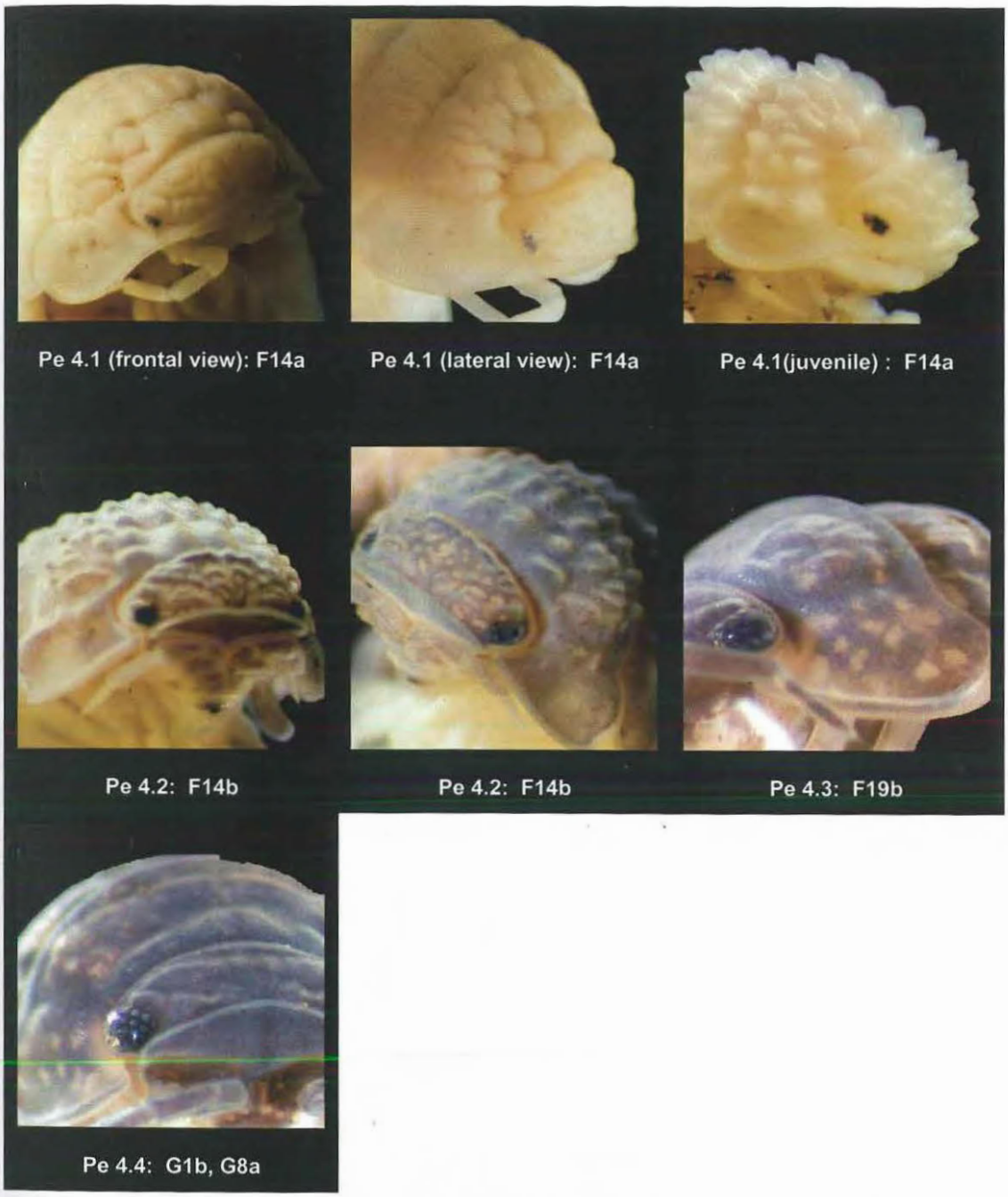


Plate 3.20. Character state Pe 4.

3.6.3.5. Pe 5 Pereon/pereonites/epimeral junction

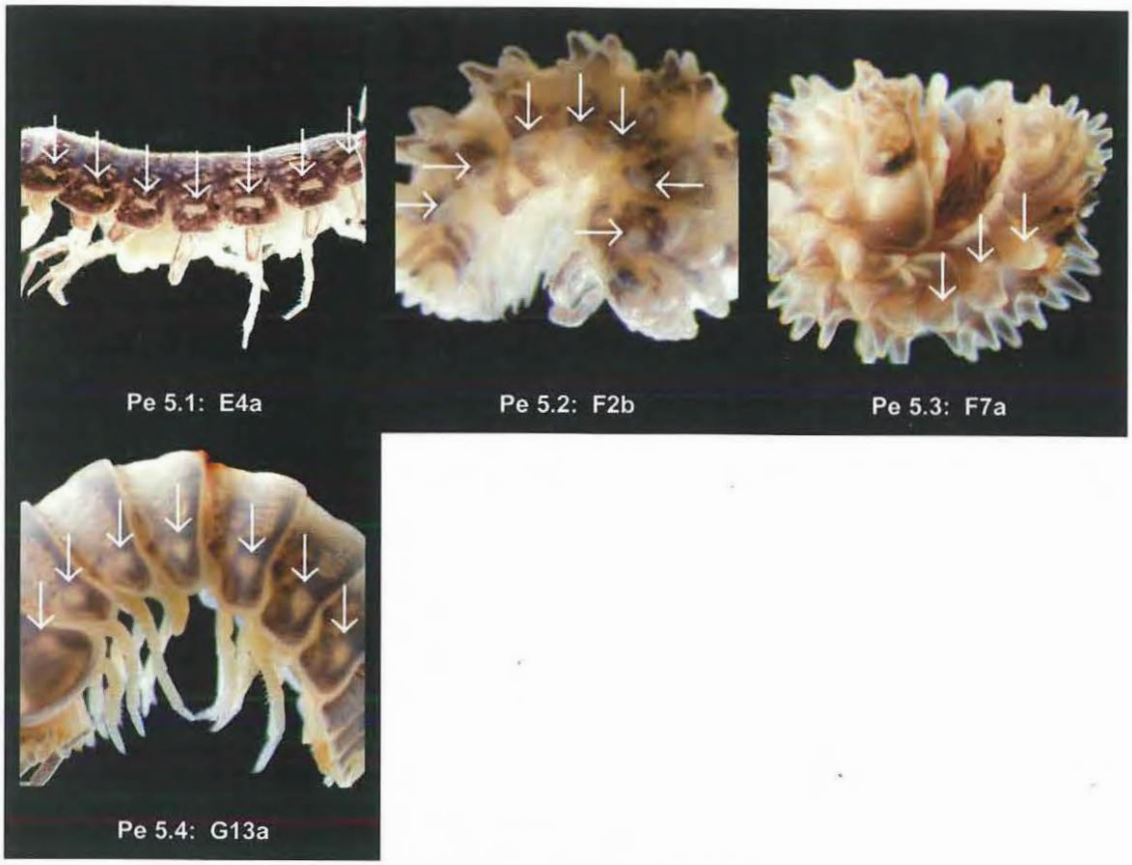


Plate 3.21. Character state Pe 5.

3.6.3.6. Pe 6 Pereon/epimera/shape

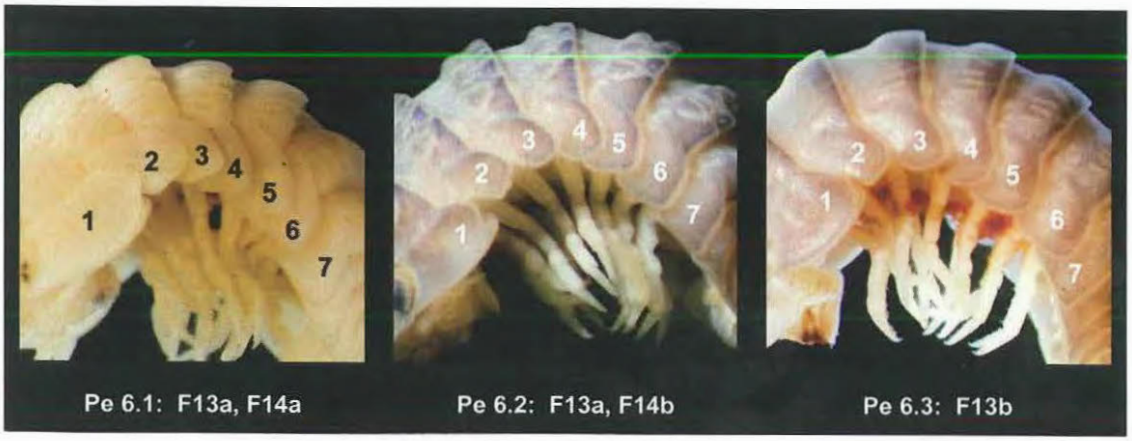


Plate 3.22. Character state Pe 6.

3.6.3.7. Pe 7 Pereon/epimera/colour

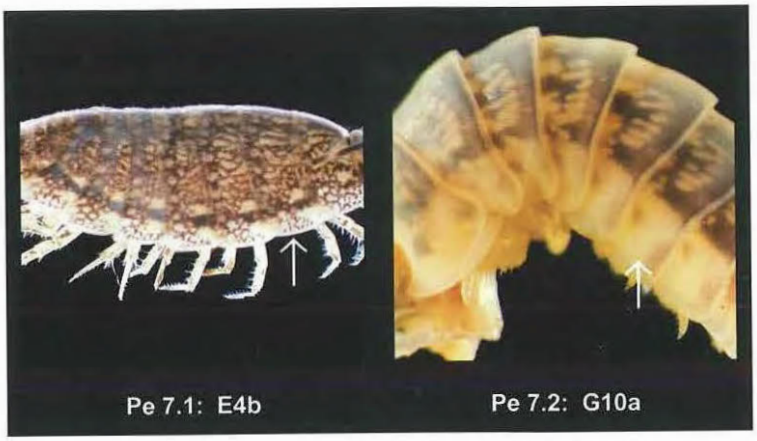


Plate 3.23. Character state Pe 7.

3.6.3.8. Pe 8 Pereon/epimera/discontinuity

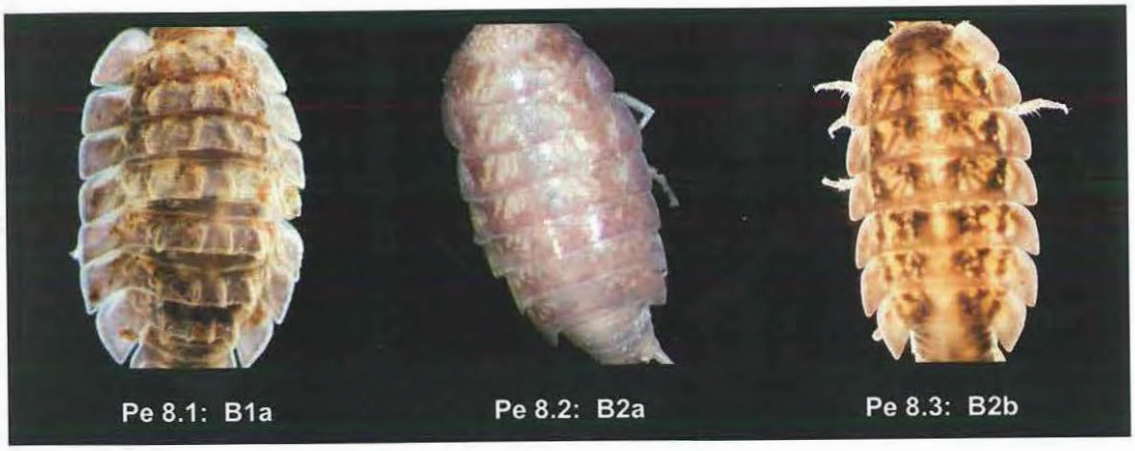


Plate 3.24. Character state Pe 8.

3.6.3.9. Pe 9 Pereon/epimera 1/inner lobe type

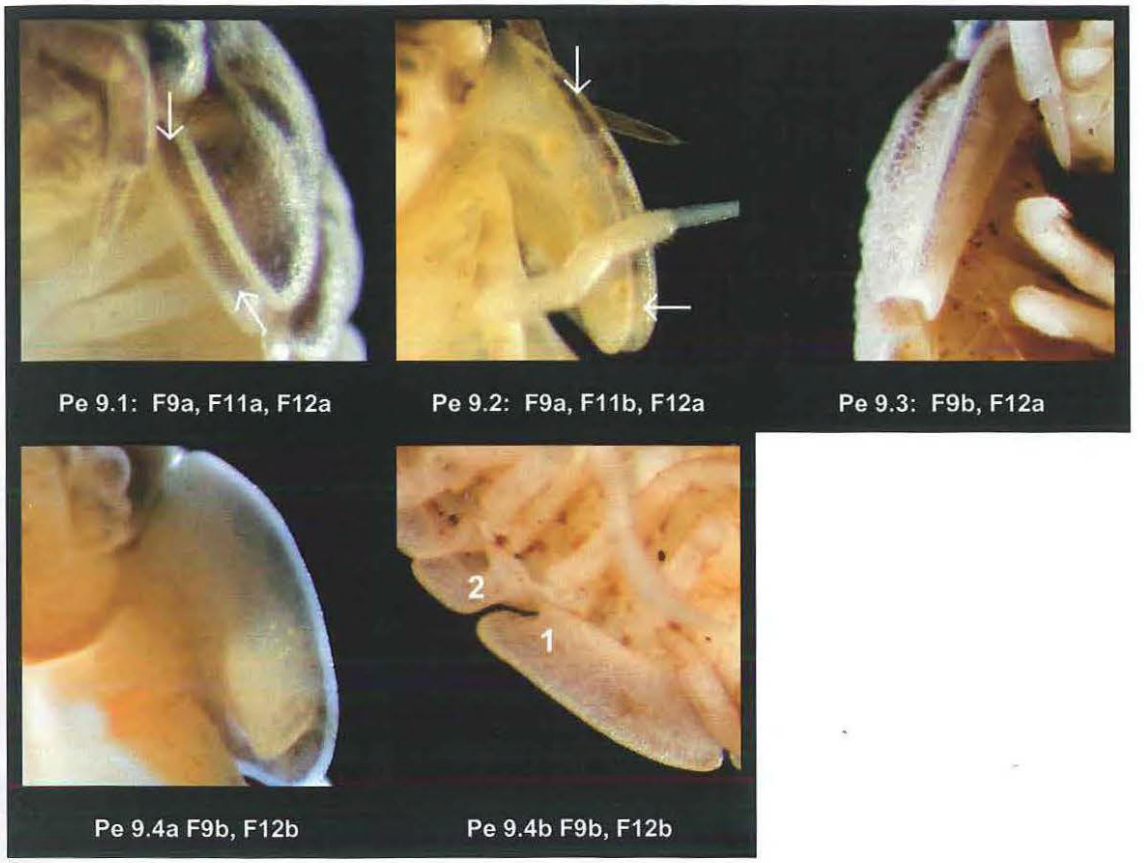


Plate 3.25. Character state Pe 9.

3.6.3.10. Pe 10 Pereon/epimera 1/shape

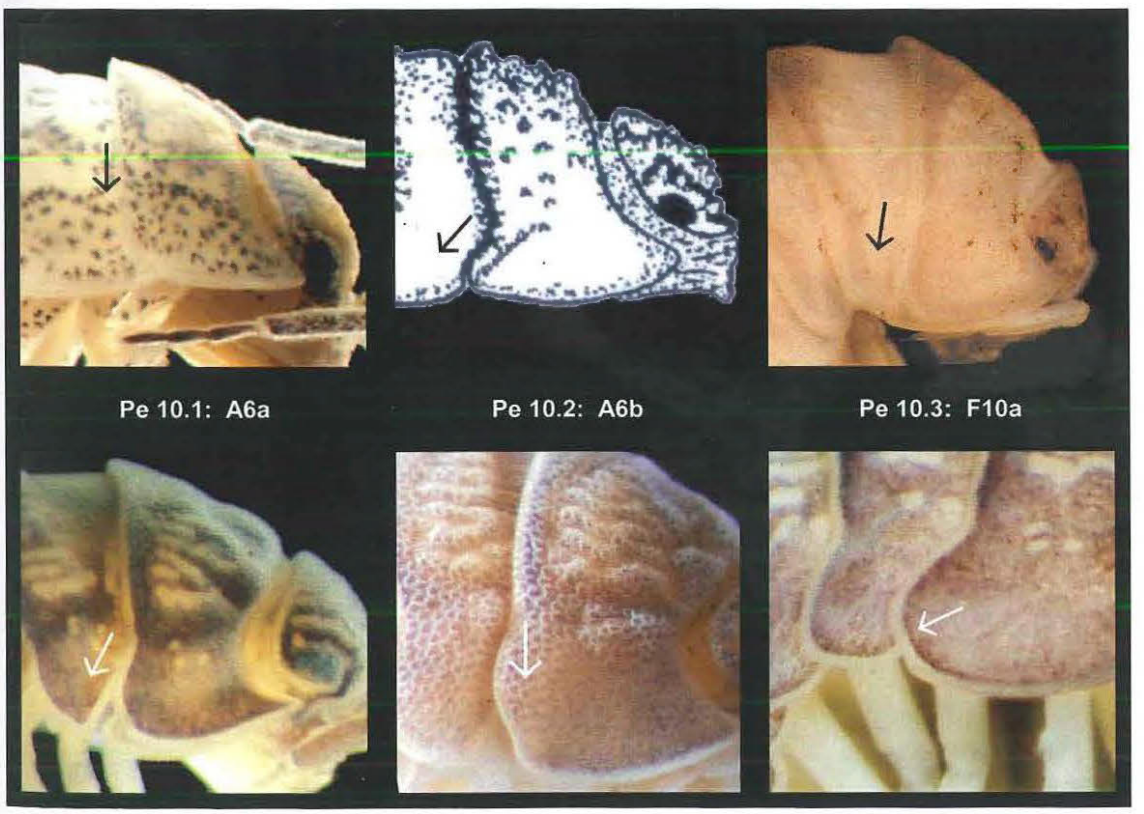


Plate 3.26. Character state Pe 10. Pe 10.2 adapted from Chilton (1917, fig.15).

3.6.3.11. Pe 11 Pereon/epimera 1/sulcus arcuatus

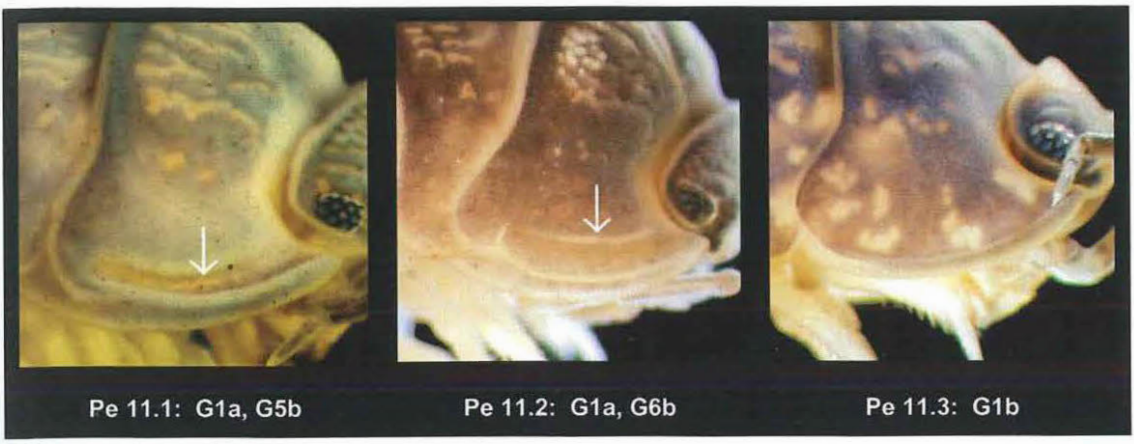
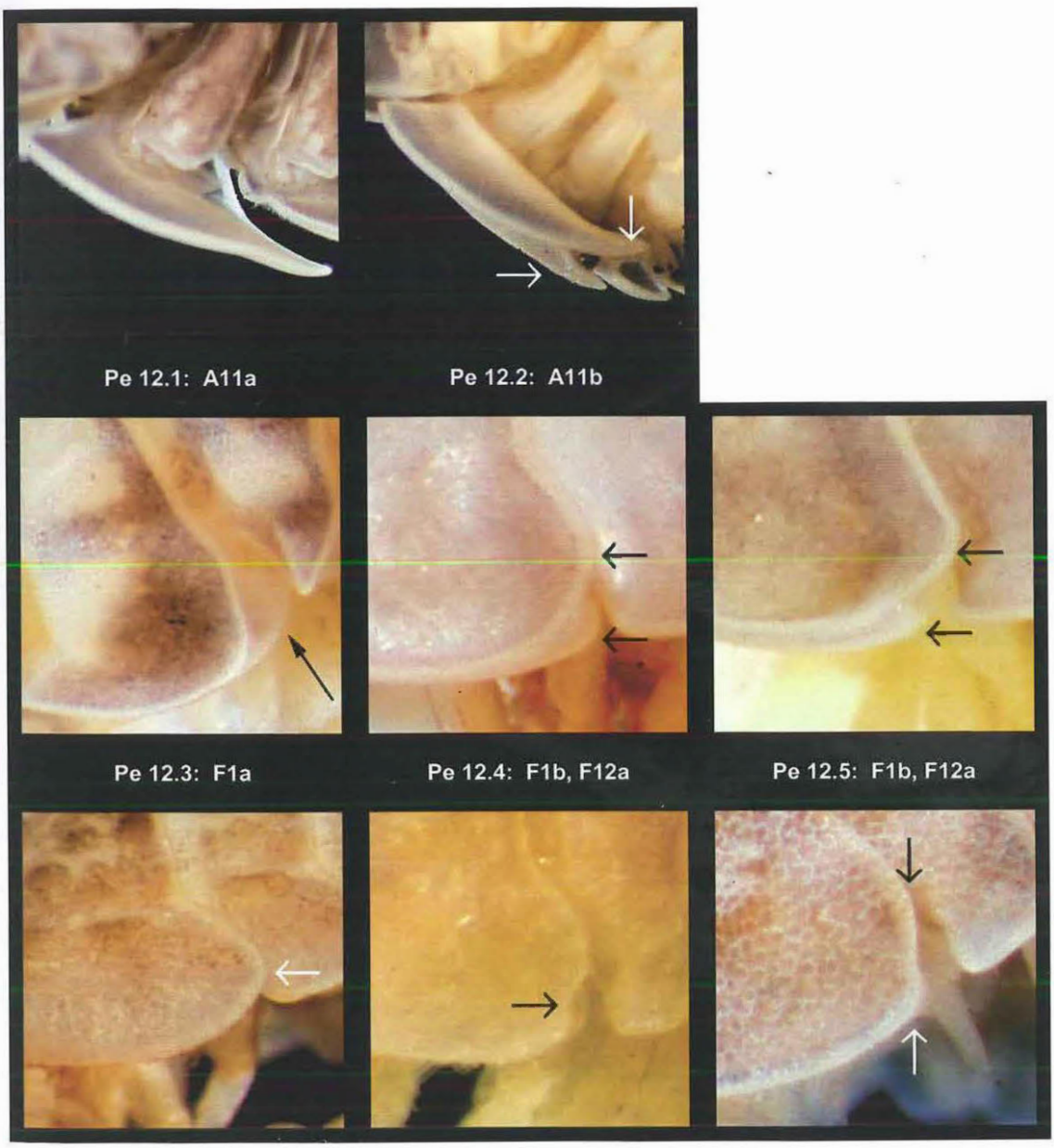


Plate 3.27. Character state Pe 11.

3.6.3.12. Pe 12 Pereon/epimera 1/articulatory lobes



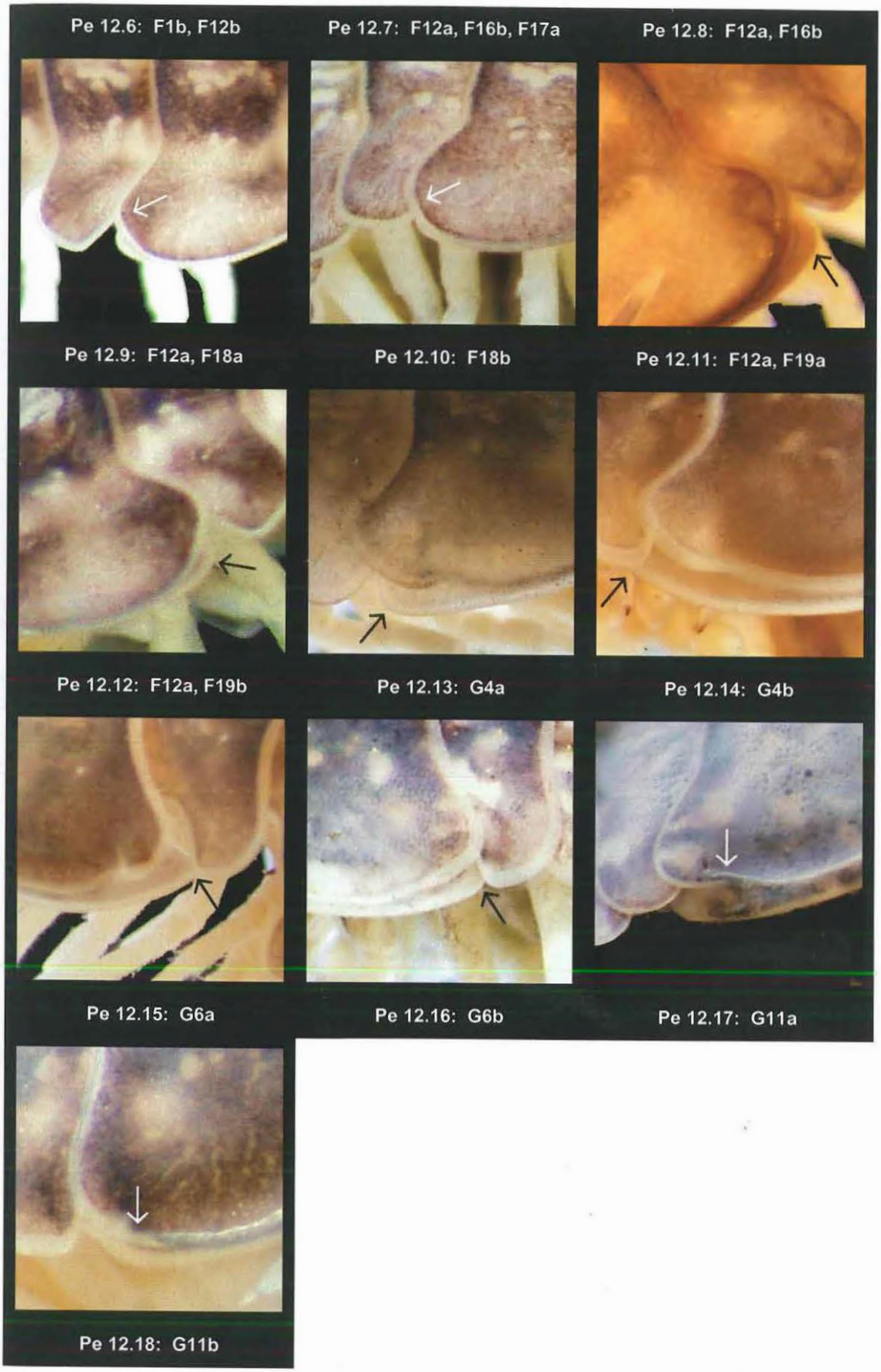


Plate 3.28. Character state Pe 12.

3.6.3.13. Pe 13 Pereon/epimera 2/shape

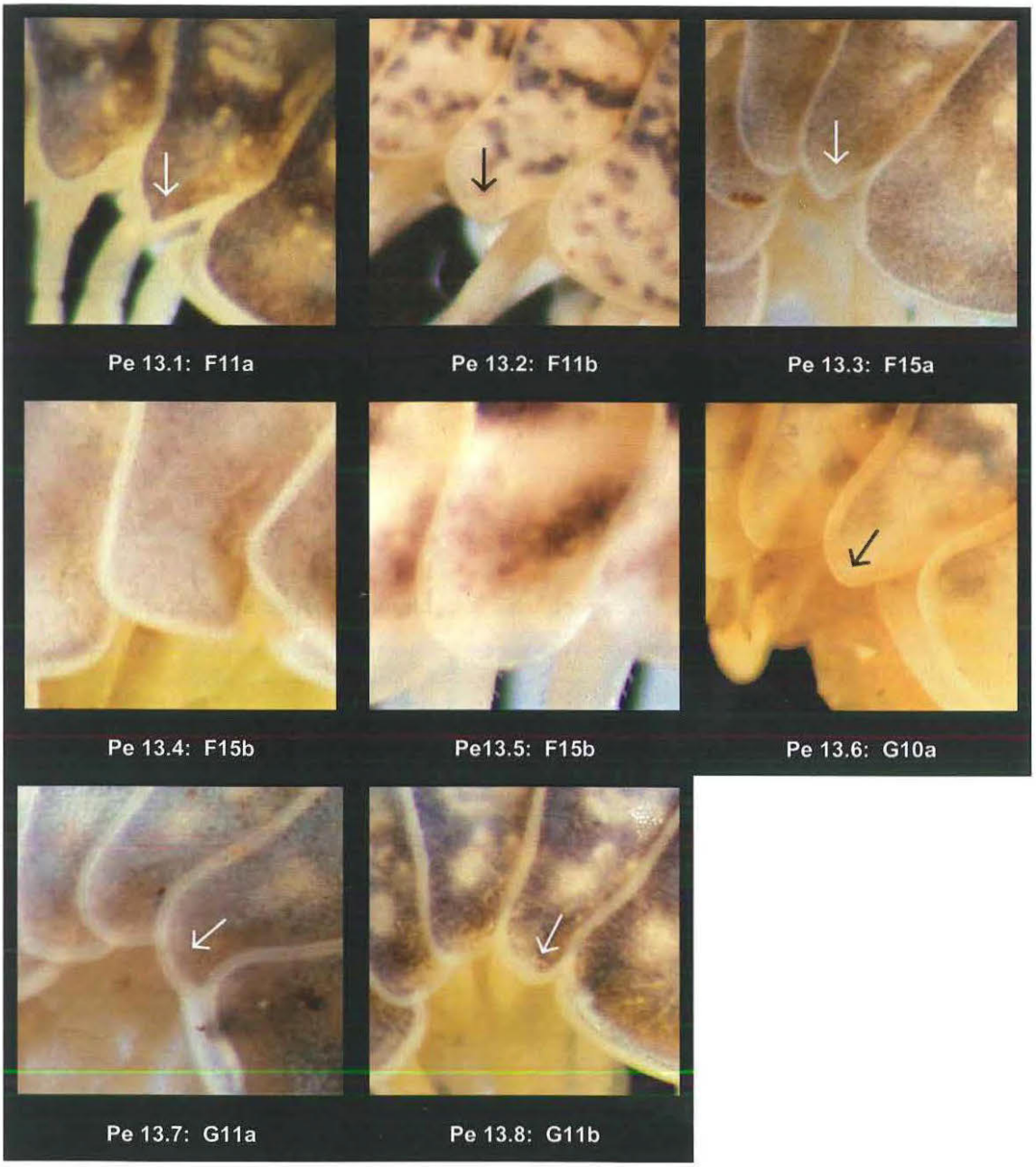


Plate 3.29. Character state Pe 13.

3.6.3.14. Pe 14 Pereon/epimera 2/inner lobe/shape

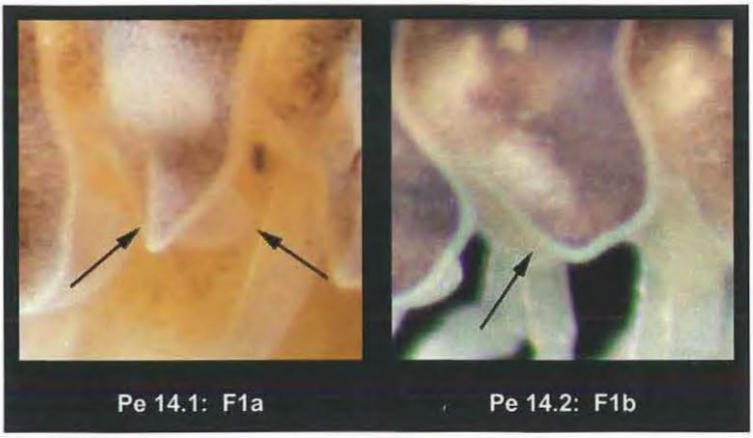


Plate 3.30. Character state Pe 14.

3.6.3.15. Pe 15 Pereon/epimera 7/shape

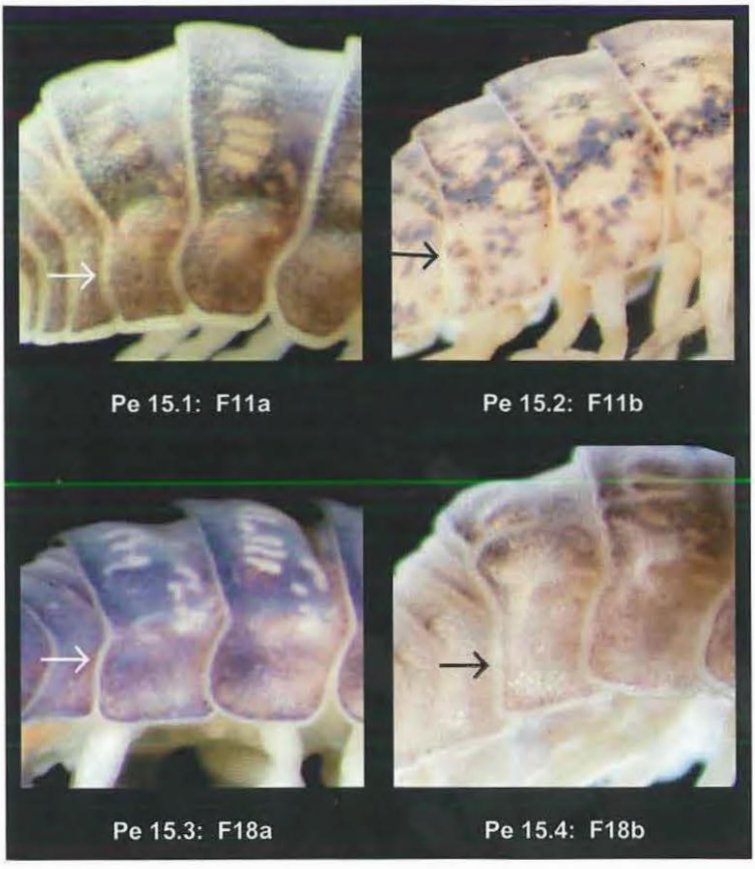


Plate 3.31. Character state Pe 15.

3.6.3.16. Pe 16 Pereon/pereopods/colour

Plate 3.32. Character state Pe 16.

3.6.3.17. Pe 17 Pereon/pereopod 1/carpus

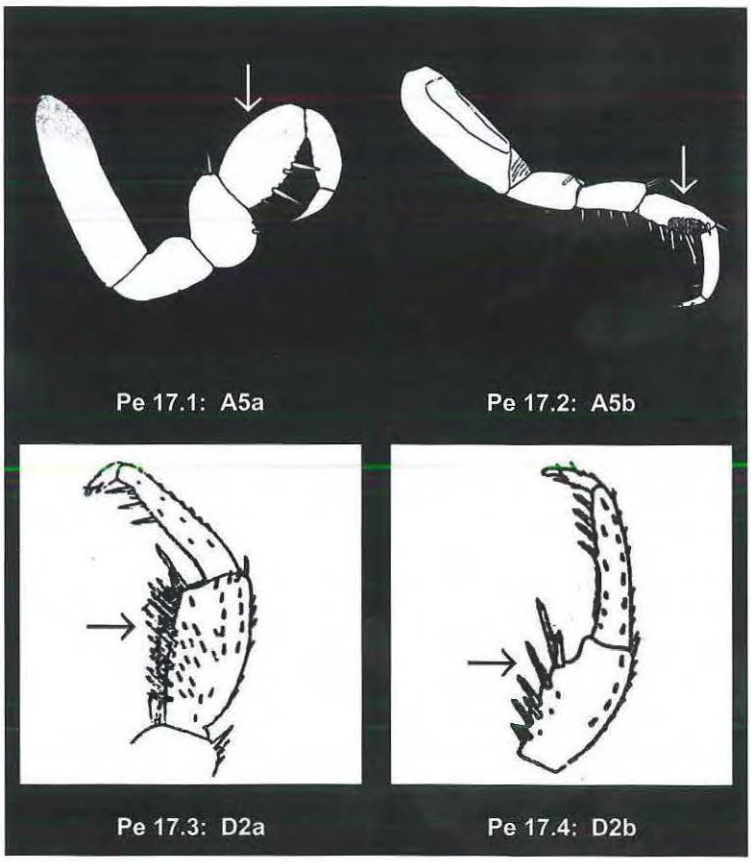


Plate 3.33. Character state Pe 17. Pe 17.1 adapted from Williams (1970, fig. 2A). Pe 17.3 and Pe 17.4 adapted form Bowley (1935 , Plate 7, fig. 13 and Plate 8, fig. 8 respectively).

3.6.4. CHARACTERS OF THE PLEOTELSON

3.6.4.1. Pl 1 Pleotelson/epimera 3, 4 and 5/shape

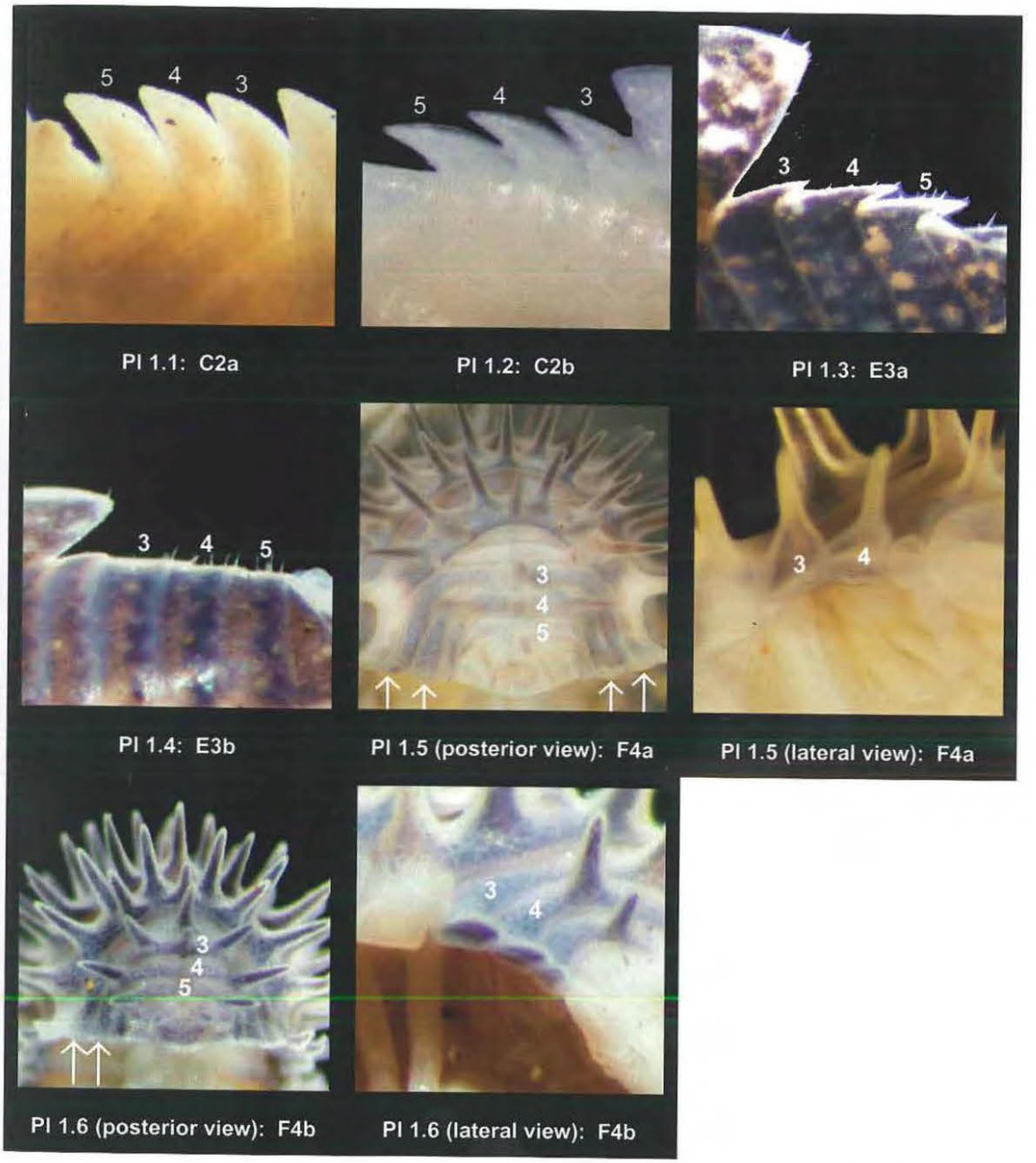


Plate 3.34. Character state Pl 1.

3.6.4.2. Pl 2 Pleotelson /pleopods/exopodites/arrangement

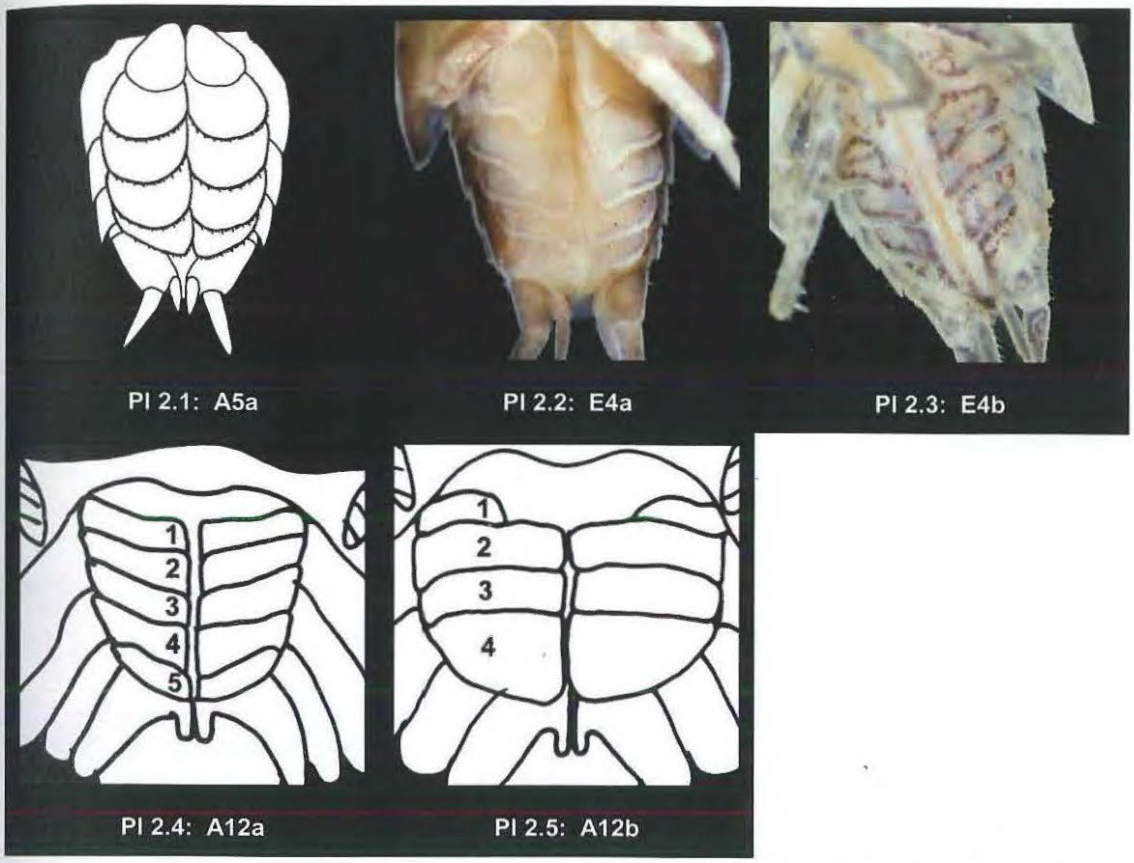


Plate 3.35. Character state Pl 2. Pl 2.1 adapted from Taiti, Ferrara & Illiffe (1995, Fig. 1F).

3.6.4.3. Pl 3 Pleotelson /pleopods 1 and 2/pleopodal lungs

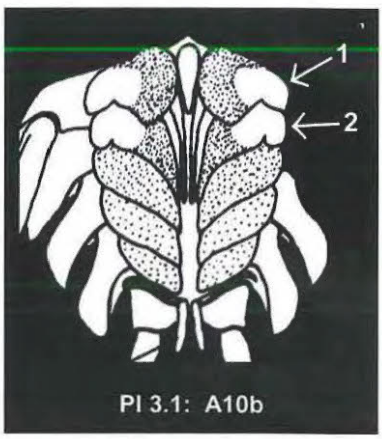


Plate 3.36. Character state Pl 3 adapted from Hopkin (1991, fig.3)

3.6.4.4. Pl 4 Pleotelson /uropods/length

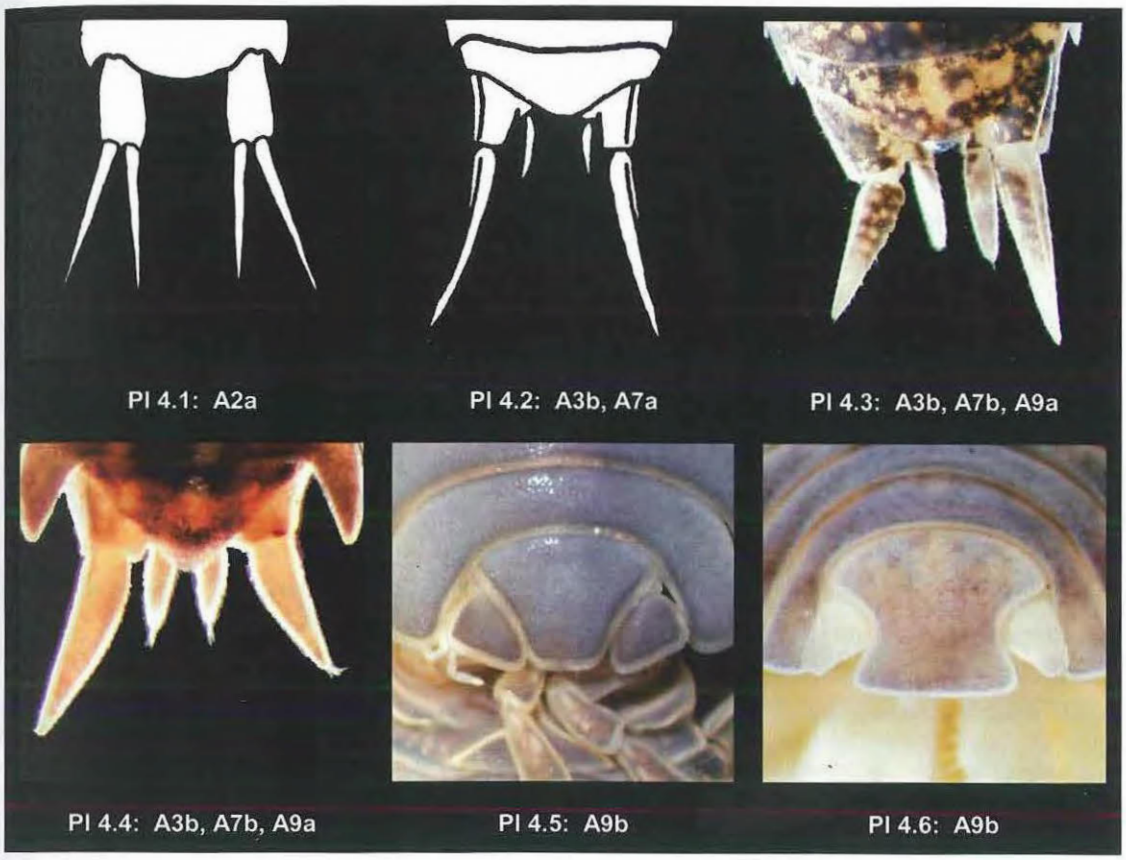


Plate 3.37. Character state Pl 4. Pl 4.1 and Pl 4.2 adapted from Hopkin (1991, fig 6a and fig 16.c respectively).

3.6.4.5. Pl 5 Pleotelson /uropod/exopodite/shape

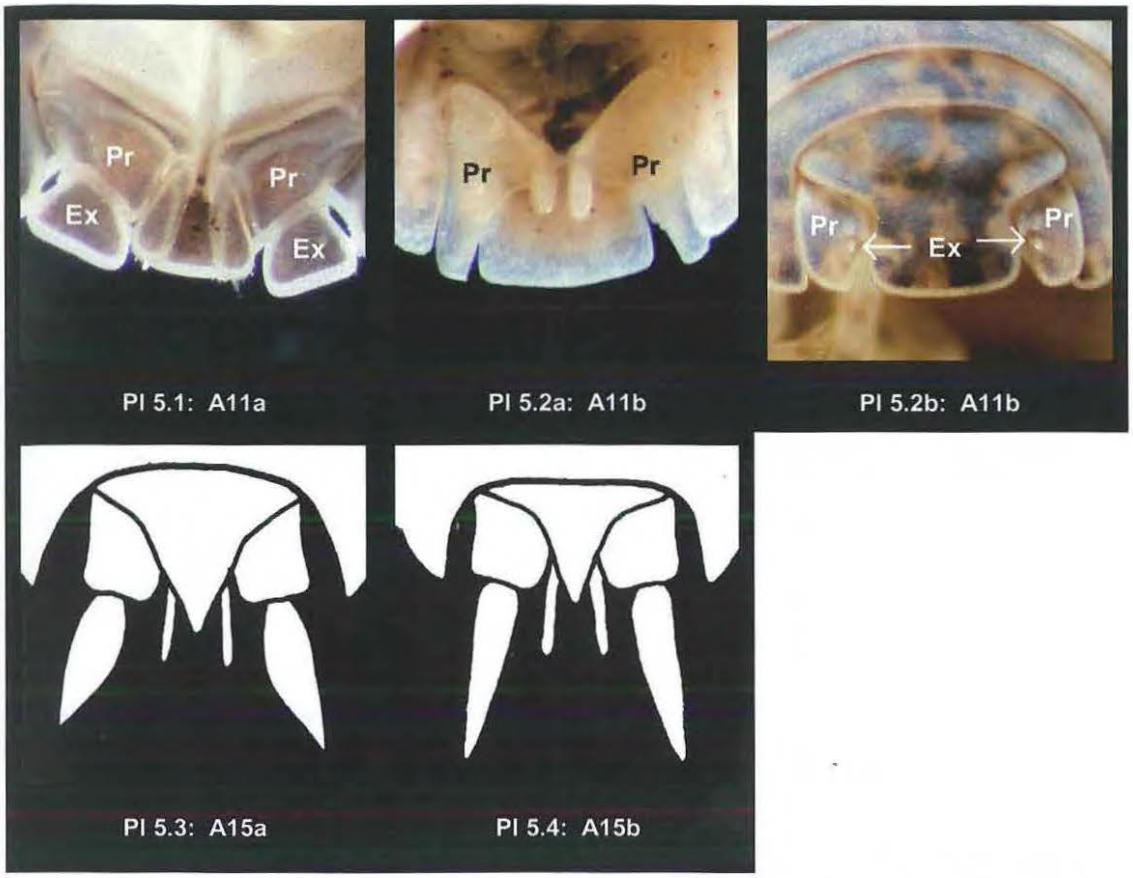


Plate 3.38. Character state Pl 5. Pl 5.4 and Pl 4.2 adapted from Hopkin (1991, fig. 6a and fig. 16c respectively).

3.6.4.6. Pl 6 Pleotelson /uropods/protopodite/shape

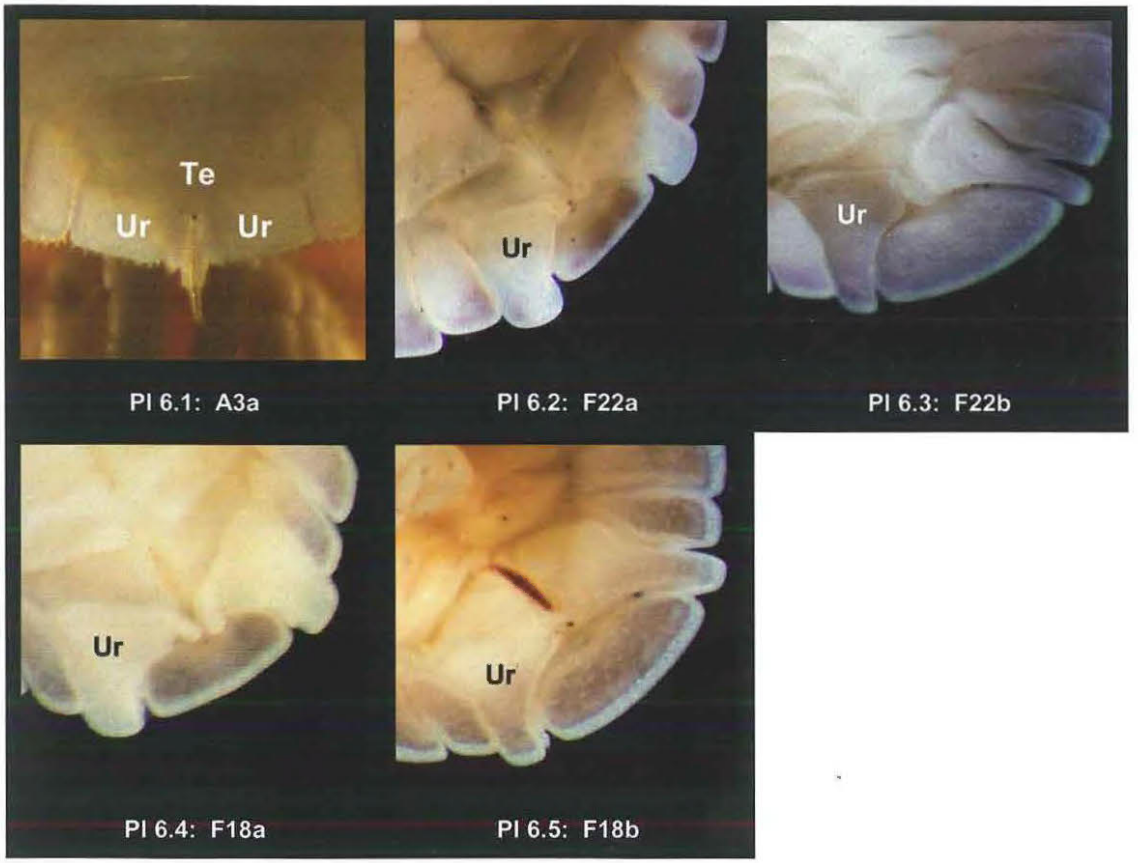
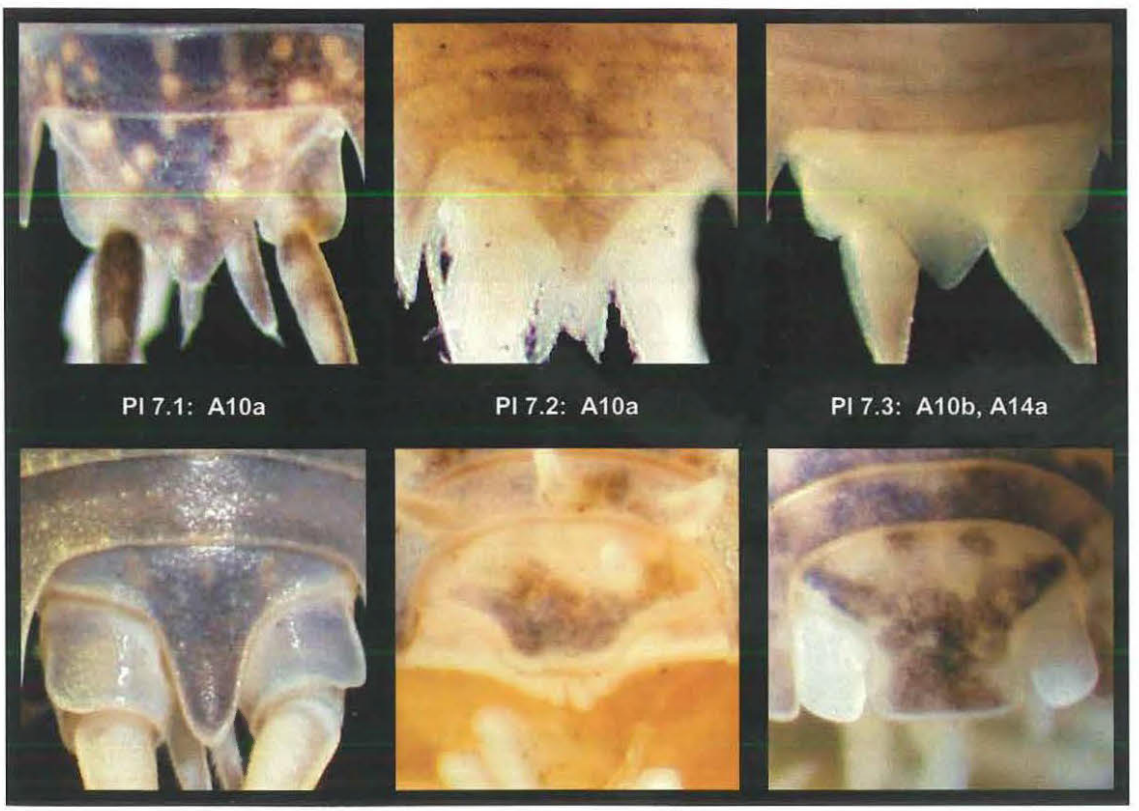


Plate 3.39. Character state Pl 6.

3.6.4.7. Pl 7 Pleotelson /telson/shape



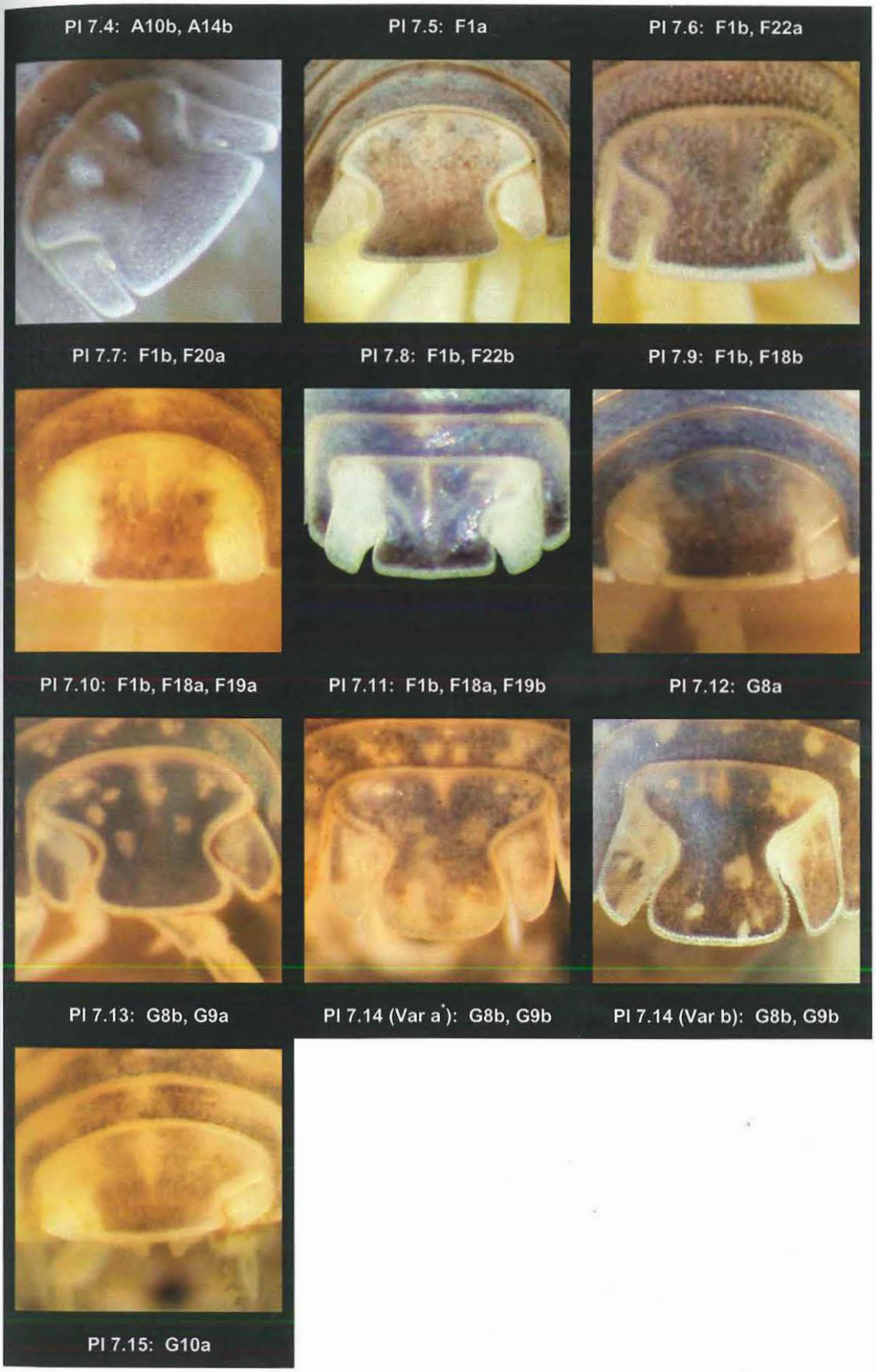


Plate 3.40. Character state Pl 7 (* this variant found only at the Porongurup Range)

3.7. FAMILY LIGIIDAE BRANDT AND RATZEBURG

Diagnosis: Non-conglobating. Flagellum of second antenna with more than 10 articles. Mandible with molar process. Eye with many (>100) ommatidia. Without pleopodal lungs in exopodites of pleopods. Uropods attached terminally and very long, projecting well beyond telson. Littoral species.

3.7.1. GENUS LIGIA FABRICIUS

3.7.1.1. Ligia sp.

Plate 3.5, He 1.4; Plate 3.8, He 4.1, Plate 3.41.

Ligia australiensis Vandel, 1973

Ligia australiensis Judd & Horwitz, 2003

MATERIAL EXAMINED. C16082, PEPPERMINT GROVE JETTY ON SWAN RIVER, -32.0000°S 115 7667°E, THRELFALL, T., 16-11-78. (SPECIMEN DRIED AND IN MANY PIECES). UNREGISTERED SPECIMEN, SWAN RIVER FORESHORE PERTH, SENT TO S. TAITI.

Diagnosis. Habitus runner. Littoral species with eye of greater than 100 ommatidia Light green/brown in colour when preserved. Uropods very long.

Remarks: A complete diagnosis of both Ligia and L. australiensis was given by Green (1961). G. Poore made a determination of the specimen (C16082) given above as L. australiensis.. However, the condition of the specimen does not permit confirmation of this. The specimen photographed below was collected after this chapter was prepared and was added later.

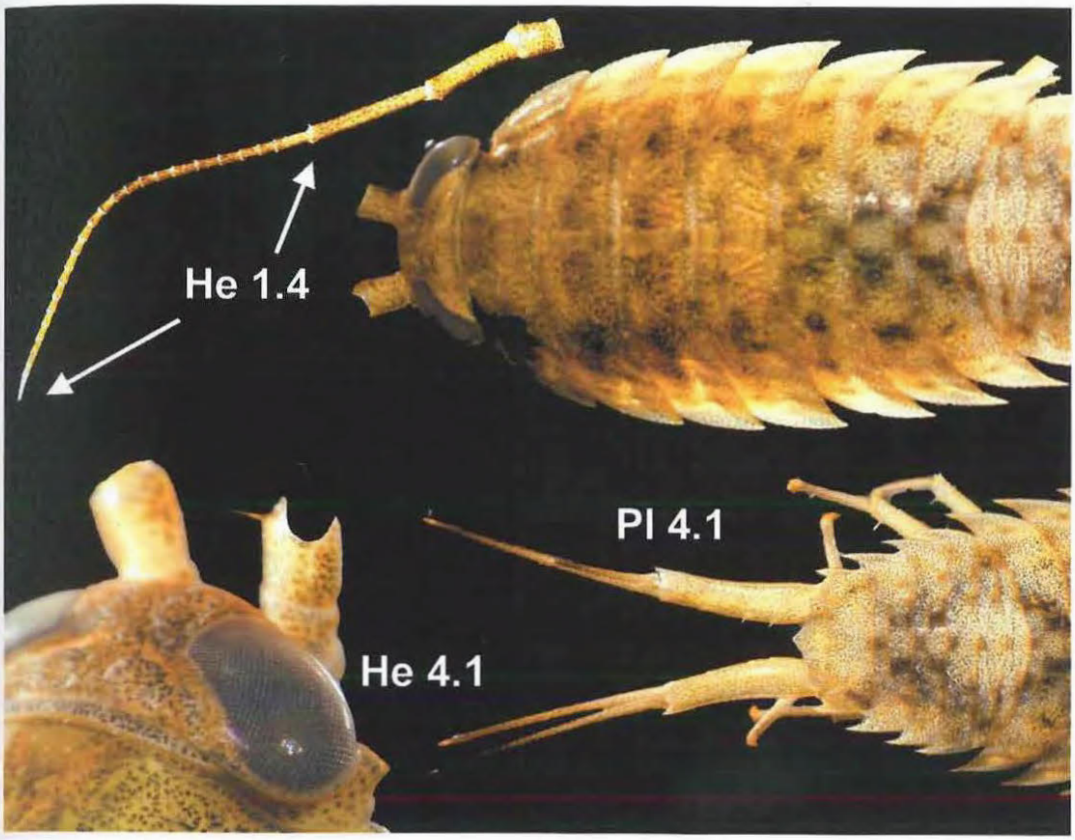


Plate 3.41. Ligia **sp. from the littoral zone of the Swan River, Perth (unregistered specimen, collected and photographed in 2002) (length 15 mm).**

3.8. FAMILY ACTAECIIDAE VANDEL

Diagnosis: Conglobating. Flagellum of second antenna with 4 articles. Frontal line of head forms a ridge. Articulatory lobes developed on pereonal epimera 1-3. Not interrupted between the pleon and pereon. Uropods extend beyond telson as posterolateral part of protopodite flattened and forms part of body outline. Pleopodal lungs in exopodites of pleopods 1-5. Body strongly convex of pale colour. Littoral species (see Lewis & Green, 1994 for complete diagnosis and key to all species). Actaeciidae is a monogeneric family (see remarks below).

3.8.1. GENUS ACTAECIA DANA

A revised diagnosis, based partly on the work of Chilton (1901) and Vandel (1964), has recently been published along with a key to the species (Lewis and Green, 1994).

3.8.1.1. Actaecia pallida Nicholls and Barnes, 1926

Plate 3.5, He 1.8; Plate 3.39, Pl 6.1; Plate 3.42.

Actaecia pallida Nicholls and Barnes, 1926

Actaecia pallida '(V)' Lewis, 1990

Actaecia pallida Lewis and Green, 1994

Actaecia pallida Judd & Horwitz, 2003

Actaecia pallida Schmidt, 2002

MATERIAL EXAMINED C30954, TWO PEOPLES BAY HERRING BAY, -34 9833°S 118 1667°E, COLLECTOR UNKNOWN, 31-05-27; C30955, NAVAL BASE, -32 2000°S 115 7833°E, NICHOLLS COLLECTION, ??-09-31, C30956, ROTTNEST ISLAND SEASHORE NEAR JETTY, -32.0000°S 115 5000°E, NICHOLLS COLLECTION, 31-03-28, C30957, COTTESLOE BEACH, -32 0000°S 115.7500°E, NICHOLLS COLLECTION, 02-09-27; C30958, NAVAL BASE, -32 2000°S 115.7833°E, NICHOLLS COLLECTION, 07-02-33; C30959, COTTESLOE, -32 0000°S 115 7500°E, NICHOLLS COLLECTION, ??-??-32; C30960, NAVAL BASE, -32 2000°S 115 7833°E, NICHOLLS COLLECTION, 24-04-38; C30961, NORTH BEACH, -31.8667°S 115.7500°E, NICHOLLS COLLECTION, ??-??-29; C30962, CITY BEACH, -31 9333°S 115.7525°E, COOPER, V C., ??-??-35; C30963, WATERMANS BAY, -31 8500°S 115.7500°E, NICHOLLS COLLECTION, ??-04-32; C30964, LEIGHTON, -32 0333°S 115.7500°E, NICHOLLS COLLECTION, 21-04-46; C30965, CITY BEACH, -31 9333°S 115.7525°E, GEORGE, R W., 27-07-58.

Diagnosis: Habitus roller. Eye round with fewer than 30 ommatidia. Pleonal epimera and uropod protopodite all with posterolateral borders truncate. Pleonal epimeron 3 extending beyond pereonal epimeron 7 and therefore forming part of body outline. Pleonal epimera 3 subquadrangular and truncate.

Remarks: After this chapter was complete, Schmidt (2002a) recognised Actaecia as forming a monophyletic group with Scyphax. He restricted the Scyphacidae s. str. to Scyphax and Actaecia. Since this is not yet well accepted, and this chapter was already prepared, Actaecia is retained in Actaeciidae sensu Vandel (1952).

Plate 3.42. Actaecia pallida **(C30955) from Naval Base (length 4 mm).**

3.9. FAMILY SCYPHACIDAE DANA

Diagnosis: Non conglobating genera known from Western Australia. Flagellum of second antenna with 4 articles (fourth may be very small). Pereon without noduli laterales. Body shallowly convex. Without pleopodal lungs in exopodites of pleopods. Littoral or secondarily aquatic species. Haloniscus has recently been included in the Scyphacidae (Taiti, Ferrara & Illiffe, 1995). However, this family probably represents a phylogenetically heterogeneous group of genera (Taiti, Ferrara & Illiffe, 1995).

3.9.1. GENERA HALONISCUS CHILTON, ALLONISCUS AND DETO CHILTON

A recent diagnosis was given by Taiti and Humphreys (2001).

3.9.1.1. Haloniscus searlei Chilton, 1920

Plate 3.3, Gm 3.1; Plate 3.5, He 1.9; Plate 3.33, Pe 17.1.

Haloniscus searlei Chilton, 1920

Philoscia salina Baker, 1926

Haloniscus searlei Williams, 1970

Haloniscus searlei Vandel. 1973

Haloniscus searlei Bunn & Green, 1982

Haloniscus searlei Taiti, Ferrara & Illiffe, 1995

Haloniscus searlei Taiti & Humphreys, 2001

Haloniscus searlei Judd & Horwitz, 2003

MATERIAL EXAMINED C3828/87, ROTTNEST ISLAND GARDEN LAKE, -32.0000°S 115.5000°E, GLAUERT, L., ??-02-30, R1; C30947/48, ROTTNEST ISLAND LAKE BAGHDAD, -32.0000°S 115.5000°E, GLAUERT, L?, 13-04-39, R1; C30949, SCARLET LAKE NEAR LAKE CLIFTON, -32.8000°S 115.6667°E, SERVENTY, D L., ??-02-28; C30950, ROTTNEST ISLAND LAKE BAGHDAD, -32.0000°S 115.5000°E, NICHOLLS COLLECTION, ??-04-28, R1, C30951, ROTTNEST ISLAND GARDEN LAKE, -32.0000°S 115.5000°E, NICHOLLS COLLECTION, ??-??-??; C30952, ROTTNEST ISLAND GARDEN LAKE, -32.0000°S 115.5000°E, COLLECTOR UNKNOWN, 14-04-34, C30953, SCARLET LAKE NEAR LAKE CLIFTON, -32.8000°S 115.6667°E, COLLECTOR UNKNOWN, 16-05-32

Diagnosis: Habitus runner/creeper. Non–conglobating, secondarily aquatic species. Body outline interrupted at junction of pereon and pleon. Carpus of pereopod 1 very broad. Pleopod exopodites broad and rounded overlapping in centre sometimes visible in dorsal view. See Williams (1970) for a complete description of this species.

Remarks: No suitable material was available to photograph so no plate was prepared. Comprehensive figures were given by Williams (1970) and a key to the species of Haloniscus by Taiti and Humphreys (2001). See also remarks for Actaecia.

3.9.1.2. Alloniscus pallidulus Budde-Lund, 1885

Plate 3.2, Gm 2.1; Plate 3 11, He 7.1, Plate 3.26, Pe10.1, Plate 3.43.

Alloniscus nicobancus Budde-Lund, 1885

Alloniscus nicobancus Budde-Lund, 1912

Alloniscus nicobancus Vandel, 1973

Alloniscus nicobancus Bunn & Green, 1982

Alloniscus pallidulus Green, Ferrara & Taiti, 1990

Alloniscus pallidulus Judd & Horwitz, 2003

MATERIAL EXAMINED: C369, NORTH FREMANTLE COASTAL LAND, -32 0500°S 115 7500°E, HAMBURG EXPEDITION, 15-10-05. C12892, ROTTNEST ISLAND ISLET 13, -32 0000°S 115 5000°E, BUNN, S., 08-05-80. C12893, ROTTNEST ISLAND ISLET 18, -32 0000°S 115 5000°E, BUNN, S., 08-05-80. C12894, ROTTNEST ISLAND ISLET 20, -32 0000°S 115 5000°E, BUNN, S., 08-05-80. C29720/1, SALT LAKE (NORTH OF JURIEN BAY), -30 1880°S 115 0200°E, JUDD, S., 14-10-98, S1. C30943/, ROTTNEST ISLAND LAKE BAGHDAD, -32 0000°S 115 5000°E, GLAUERT, L?, 13-04-39, R1. C30945, ROTTNEST ISLAND LAKE BAGHDAD SE SHORE, -32 0000°S 115 5000°E, COLLECTOR UNKNOWN, 25-11-45. C30946, ROTTNEST ISLAND SERPENTINE LAKE, -32 0000°S 115 5000°E, COLLECTOR UNKNOWN, ??-??-??

Diagnosis: Habitus runner/clinger. Non–conglobating, littoral species. Body outline not interrupted at junction of pereon and pleon. Pereonites smooth with pigment visible as individual chromatophores. Head with lateral lobes rounded. Posterior margin of pereonal epimera 1 straight not angled backwards.

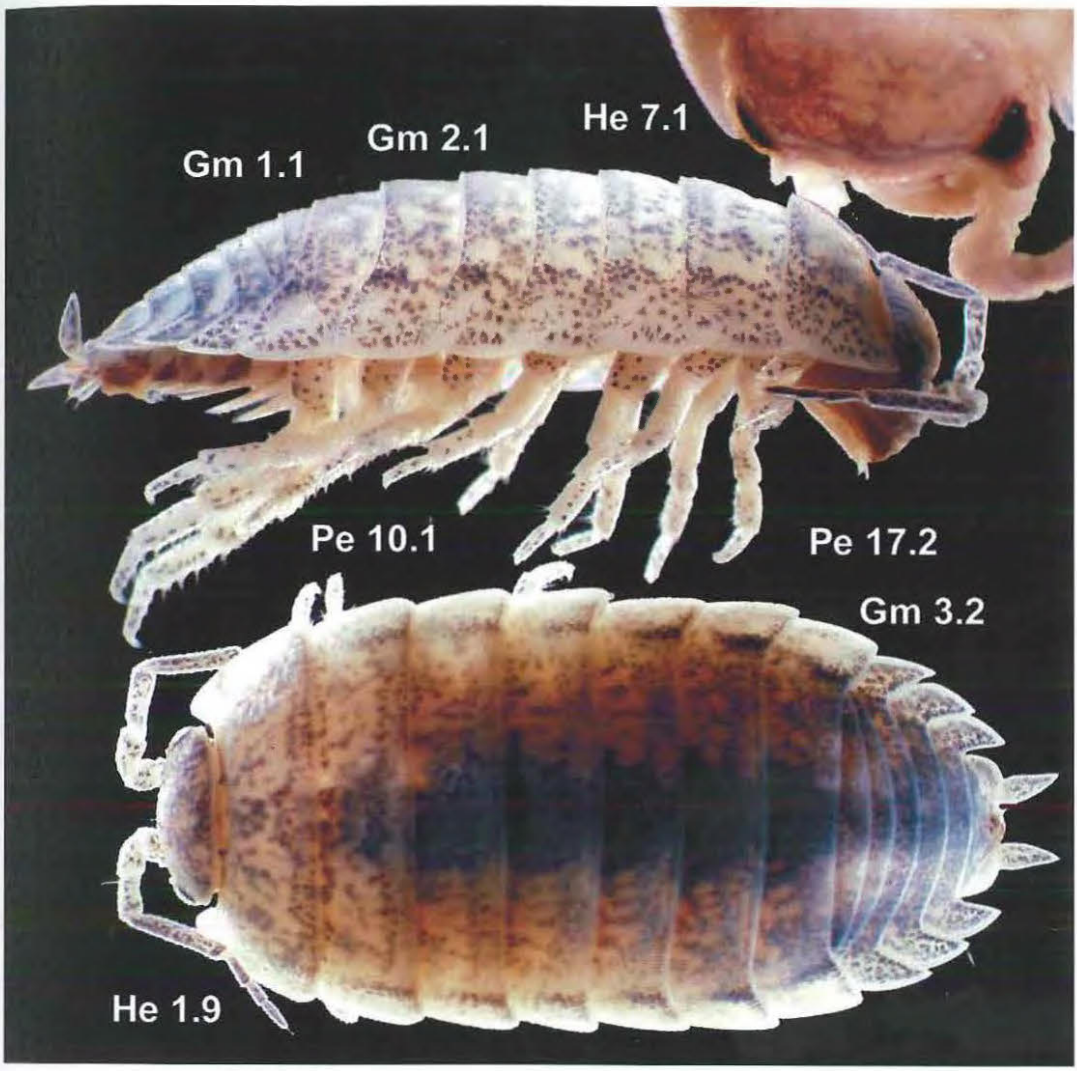


Plate 3.43. Alloniscus pallidulus (C29720/1) from the shore of a coastal salt lake north of Jurien Bay (length 8 mm).

3.9.1.3. Deto marina Chilton, 1884

Plate 3.3, Gm 3.2; Plate 3.11, He 7.2; Plate 3.26, Pe 10.2. Plate 3.44.

Philougna manna Chilton, 1884

Philygna manna Chilton, 1886

Deto marina Budde-Lund 1906

Deto marina Chilton 1901

Deto n. sp. Budde-Lund 1912

Deto manna Chilton 1915

Deto marina Chilton 1917

Deto manna Vandel, 1973

Deto marina Bunn & Green, 1982

Deto manna Schmidt, 2002

Deto marina Judd & Horwitz, 2003

MATERIAL EXAMINED C1401, FRESHWATER BAY, SWAN RIVER, -32 0000°S 115 7833°E, GLAUERT, L., ??-??-23, C12891, ROTTNEST ISLAND ISLET 30, -32 0000°S 115 5000°E, BUNN, S , 07-05-80, C18421, SWAN RIVER FRESHWATER BAY, -32 0000°S 115 7833°E, BENNETT, E W , 24-06-30, C30941, ROTTNEST ISLAND LAKE BAGHDAD, -32 0000°S 115 5000°E, NICHOLLS COLLECTION, 01-04-28, R1, C30942, TWO PEOPLES BAY, -34 9833°S 118 1667°E, NICHOLLS COLLECTION, ??-01-35 UNREGISTERED SPECIMEN, SWAN RIVER FORESHORE PERTH, SENT TO S TAITI

Diagnosis: Habitus clinger Non-conglobating, littoral species. Pereonites tuberculate. Head with lateral lobes slightly truncate and with prominent central triangular projection.. Posterior margin of pereonal epimera 1 projecting backwards. For comprehensive descntions and figures see Chilton (1917), Green (1961) and Schmidt (2002a).

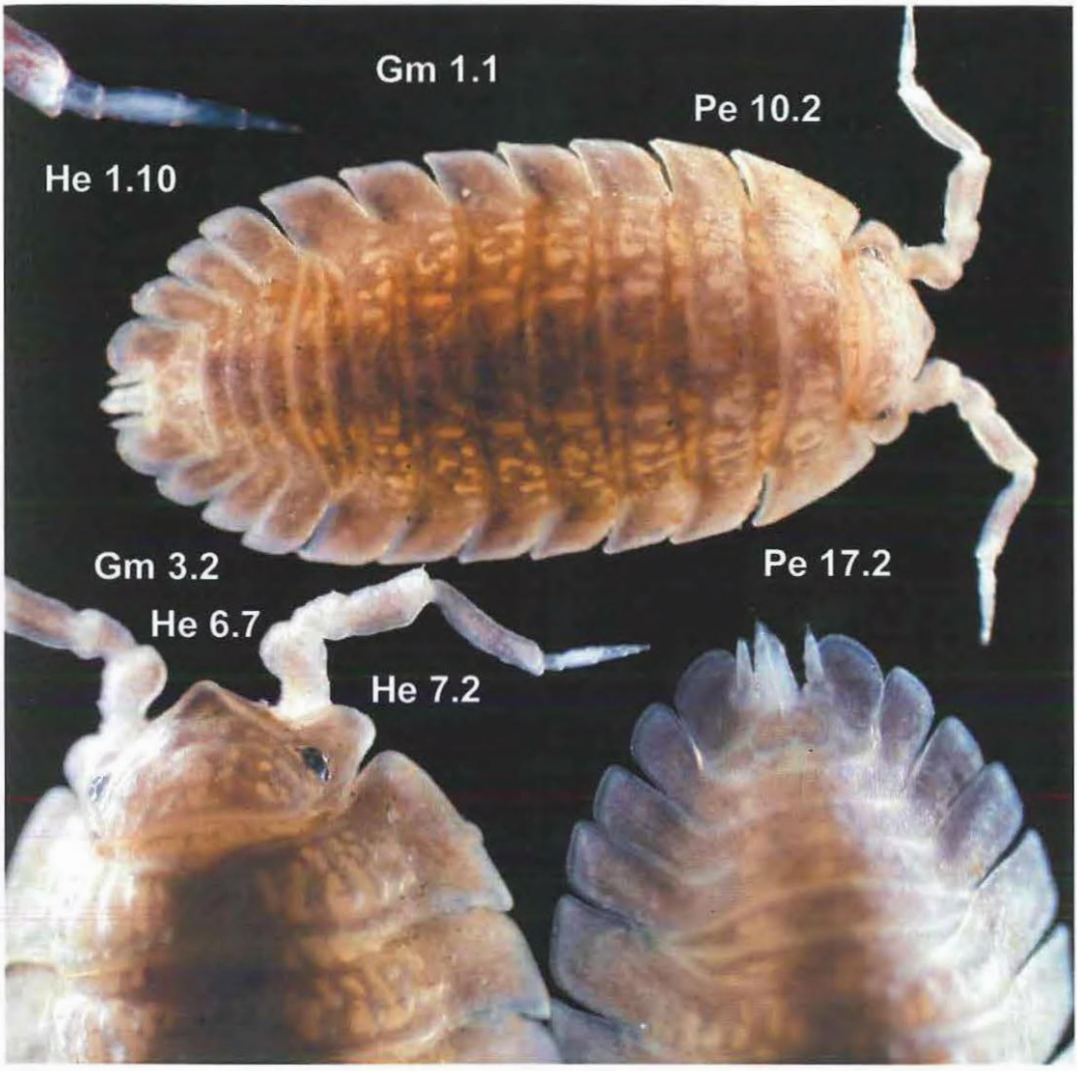


Plate 3.44. Deto marina **from the littoral zone of the Swan River estuary, Perth (unregistered specimen collected and photographed in 2002) (length 6 mm).**

3.10. FAMILY HALOPHILOSCIIDAE VERHOEFF

3.10.1. GENUS HALOPHILOSCIA

3.10.1.1. Halophiloscia couchii Kinahan, 1858

Plate 3.16, He 12.1; Plate 3.37, Pl 4.2.

Halophiloscia couchii Kinahan, 1858

Halophiloscia couchii Bunn & Green, 1982

Halophiloscia couchii Judd & Horwitz, 2003

MATERIAL EXAMINED C1396, FRESHWATER BAY, SWAN RIVER, -32.0000°S 115 7833°E, GLAUERT, L., ??-??-23, C1402, FRESHWATER BAY, SWAN RIVER, -32 0000°S 115 7833°E, GLAUERT, L., ??-??-23, C1403/4, FRESHWATER BAY, SWAN RIVER, -32 0000°S 115 7833°E, COLLECTOR UNKNOWN, ??-??-??, C2220/3, ROTTNEST ISLAND, POINT CLUNE, -31 9830°S 115 5170°E, GLAUERT, L., ??-??-27, C2368, PEPPERMINT GROVE PERTH, -32 0000°S 115.7667°E, GLAUERT, L., ??-??-27, C31769, FRESHWATER BAY, SWAN RIVER, -32.0000°S 115 7833°E, COLLECTOR UNKNOWN, ??-??-??.

Diagnosis: Habitus runner. Non conglobating, introduced littoral species. Antenna 2 very long, about two thirds length of animal from base to tip, flagellum with 3 articles. Pleonal epimera 3-5 small therefore body outline interrupted between pereon and pleon. Without pleopodal lungs in exopodites of pleopods. Uropods long with exopodite much longer than endopodite.

Remarks: No suitable material was available to photograph so no plate was prepared. Determinations are based on the fact that the species has already been recorded from the region (Bunn & Green, 1982) and confirmed using the key and descriptions by Hopkin (1991).

3.11. FAMILY ARMADILLIDIIDAE BRANDT

Diagnosis: Flagellum of second antenna with 2 articles. Raised triangular shield (scutellum) on central frontal part of head. Without interlocking lobes on pereonal epimera. Body outline not interrupted between the pleon and pereon. Uropod exopodite flattened and occupying space between pleonal epimeron 5 and telson. Pleopodal lungs present in pleopod exopodites 1 & 2. Body strongly convex. Telson sub-quadrangular or sub-triangular with apex blunt. Introduced synanthropic species.

3.11.1. GENUS ARMADILLIDIUM

3.11.1.1. Armadillidium vulgare Latreille, 1804

Plate 3.28, Pe 12.1; Plate 3.37, Pl 4.5; Plate 3.38, Pl 5.1; Plate 3.43

Armadillidium vulgare Latreille, 1804

Armadillidium vulgare Bunn & Green, 1982

Armadillidium vulgare Judd & Horwitz, 2003

MATERIAL EXAMINED: C12913, NEDLANDS GARDEN, -31 9833*S 115 8000*E, BUNN, S , 19-04-80; C19554, SUBIACO 192 YORK STREET, -31 9500*S 115 8167*E, JONES, D S , ??-10-86, C29706, NEDLANDS UNIVERSITY OF W A, -31 9833*S 115 8000*E, SPRINGETT, J A , 15-11-71, U1; C29708, SUBIACO, -31 9500*S 115 8167*E, JONES, D S , ??-11-85; C29710, SUBIACO 192 YORK STREET, -31 9500*S 115 8167*E, JONES, D S , ??-10-86, C29712, SUBIACO 192 YORK STREET, -31 9500*S 115 8167*E, JONES, D S , ??-10-86, C29713, MOUNT PLEASANT GARDEN, -32 0333*S 115 8500*E, UNSWORTH, C , 18-07-89, U1; C29717, GIDGEGANNUP WATERFORD ROAD, -31 8500*S 116 1833*E, HARVEY, M S , 12-01-92, L10, C29791, TUART HILL, -31 8806*S 115 8589*E, HARVEY, M. S & WALDOCK, J M , 21-03-94, P3, C29800, TUART HILL, -31 8803*S 115 8583*E, HARVEY, M S. & WALDOCK, J M , 21-03-94, P3, C31809, CITY BEACH, UNIVERSITY ZOOLOGY DEPARTMENT, -31.9333*S 115 7525*E, SPRINGETT, J. A., ??-09-71, C31810, WANNEROO, -31 7550*S 115 8000*E, NAGY, G., 23-05-86; C31811, MOUNT LAWLEY, -31 9333*S 115 8833*E, TERRY, D , 28-06-86, U1; C31812, LESMURDIE, -32 0000*S 116 0500*E, CAR, C A , ??-09-92, P1; C31813/4, GIDGEGANNUP WATERFORD ROAD, -31 8500*S 116.1833*E, HARVEY, M S & WALDOCK, J M , 12-02-92, R1, C31815, JOONDALUP EDITH COWAN UNIVERSITY CAMPUS, -31 7550*S 115.7833*E, JUDD, S , ??-03-99, P3, C31816, PERTH, -31 9500*S 115 8500*E, MAJER, J. D , 05-08-87, C32286, LANDSDALE SCHOOL, -31 8206*S 115 8503*E, DELL, J., 15-10-95, P2, C32287, TUART HILL, -31 8806*S 115 8589*E, WALDOCK, J M , 07-11-94, P3, C32288, TUART HILL, -31 8806*S 115 8589*E, WALDOCK, J M ET AL , 18-11-93, P3; C32289, TUART HILL, -31 8803*S 115 8583*E, WALDOCK, J. M , 07-01-94, P3; C32290, TUART HILL, -31 8806*S 115 8589*E, HARVEY, M S & WALDOCK, J. M , 19-05-94, P3; C32291, MT HENRY, -32 0314*S 115 8622*E, DELL, J , 11-12-94, P2; C32292, BOLD PARK, -31 9372*S 115 7711*E, HOW, R., 20-11-95, P2, C32293, HEPBURN HEIGHTS, -31 8183*S 115.7672*E, WALDOCK, J. M. & HARVEY, M. S., 28-11-95, P3, C32294, MT CLAREMONT, -31 9611*S 115 7667*E, HOW, R., 31-10-94, P2, C32295, MT CLAREMONT, -31 9608*S 115 7656*E, HOW, R , 31-10-94, P2; C32296, TALBOT ROAD RESERVE, -31 8733*S 116 0478*E, DELL, J , 29-08-93, P2, C32297, TALBOT ROAD RESERVE, -31 8731*S 116 0461*E, DELL, J , 29-08-93, P2

Diagnosis: Habitus roller. Conglobating, introduced and very common synanthropic species. Without dark solid patch of pigment on pereonal epimeron 7. Prominent scutellum raised to about same height of frontal ridge.

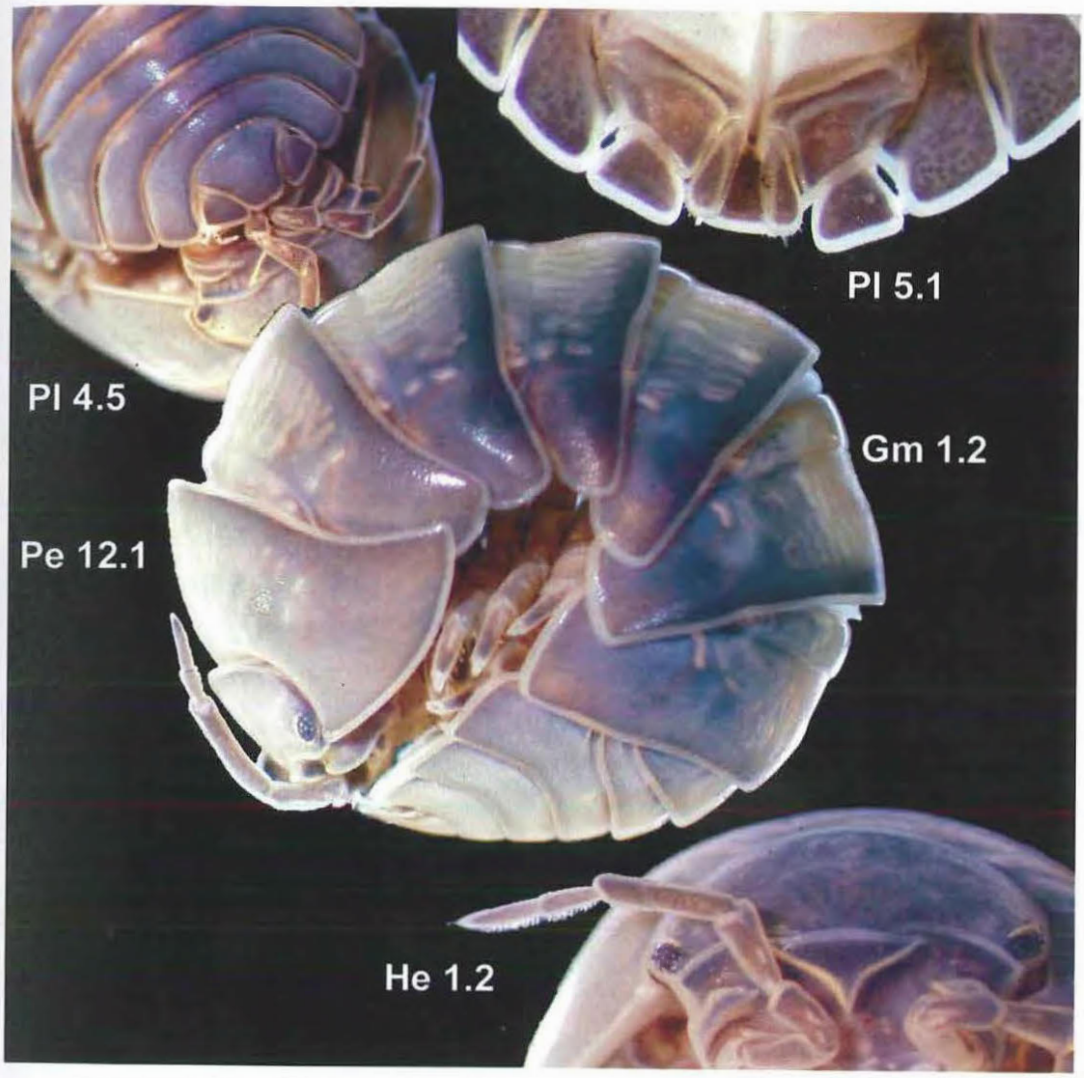


Plate 3.45. Armadillidium vulgare from Gidgegannup (C31813/4) (length 13 mm).

3.12. FAMILY PORCELLIONIDAE BRANDT AND RATZEBURG

Diagnosis: Non-conglobating, introduced species, usually synanthropic. Flagellum of second antenna with 2 articles. Head with prominent lateral lobes and sometimes a medial lobe. Pleonal epimera 3-5 large or moderate size therefore body outline not, or only slightly, interrupted between pereon and pleon. Exopodite of uropod extending backward well beyond telson. Pleopodal lungs present in pleopods exopods 1 & 2. Body shallowly convex. Telson subtriangular with sides indented.

3.12.1. GENUS PORCELLIONIDES

3.12.1.1. Porcellionides pruinosus (Brandt, 1853)

Plate 3.3, Gm 3.5; Plate 3.46.

Metoponorphus pruinosus Brandt, 1885

Metoponorphus pruinosus Budde-Lund, 1912

Metoponorphus pruinosus Wahrberg, 1922

Metoponorphus pruinosus Vandel, 1973

Metoponorphus pruinosus Bunn & Green, 1982

Porcellionides pruinosus Judd & Horwitz, 2003

MATERIAL EXAMINED: C384, MUNDARING WEIR WESTERN SLOPES OF DARLING RANGES, -31 9500°S 116.1667°E, HAMBURG EXPEDITION, 09-08-05; C397, NORTH FREMANTLE COASTAL LAND, -32 0500°S 115.7500°E, HAMBURG EXPEDITION, 30-08-05, C1156, COTTESLOE, -32 0000°S 115 7500°E, GLAUERT, L., ??-07-23, U1; C1630/7, GINGIN, -31.3500°S 115 9167°E, GLAUERT, L., ??-04-25; C2073/4, ROTTNEST ISLAND URSULA'S LAKE, -32.0000°S 115 5000°E, GLAUERT, L., ??-08-27; C2097/100, ROTTNEST ISLAND LONGREACH BAY, -32 0000°S 115.5000°E, GLAUERT, L., ??-??-27; C2139/40, ROTTNEST ISLAND MT HERSCHELL, -32 0000°S 115 5000°E, GLAUERT, L., ??-??-27; C2159/70, ROTTNEST ISLAND LAKE HERSCHELL NORTH SHORE, -32.0000°S 115.5000°E, GLAUERT, L., ??-??-27; C2711/32, ROTTNEST ISLAND NORTH POINT, -32.0000°S 115.5100°E, GLAUERT, L., ??-??-28; C2789/813, ROTTNEST ISLAND MT HERSCHELL, -32 0000°S 115 5000°E, GLAUERT, L., ??-??-28; C2828, ROTTNEST ISLAND NORTH POINT, -32 0000°S 115 5100°E, GLAUERT, L., ??-??-28; C2845, ROTTNEST ISLAND SERPENTINE LAKE, -32.0000°S 115.5000°E, GLAUERT, L., ??-09-28, C10828, SOUTH PERTH, -31 9833°S 115 8667°E, BARNES, H. M., 15-02-26; C11619, AUGUSTA LABYRINTH CAVE, -34.3167°S 115 1500°E, BYRNE, G., 27-01-63, A10; C12911, NEDLANDS, -31 9833°S 115.8000°E, BUNN, S., 19-04-80, U1, C12912, ROTTNEST ISLAND LIGHTHOUSE SWAMP, -32 0000°S 115.5000°E, BUNN, S., 05-02-80; C18409, APPLECROSS, -32 0167°S 115 8333°E, RILEY, G. M., 13-10-63; C30933, NILGEN NATURE RESE-98, R4, C30938, NAMBUNG NATIONAL PARK LAKE THETIS, -30 5070°S 115.0820°E, JUDD, S., 16-10-98, L70, C30939, NAMBUNG NATIONAL PARK LAKE THETIS, -30 5070°S 115.0820°E, JUDD, S., 16-10-98, G30, C30940, NAMBUNG NATIONAL PARK LAKE THETIS, -30 5070°S 115.0820°E, JUDD, S., 16-10-98, L10, C31799, CITY BEACH, UNIVERSITY ZOOLOGY DEPARTMENT TILTON TERRACE, -31 9333°S 115 7525°E, SPRINGETT, J. A., ??-10-71; C31800, WEMBLEY 204 HARBOURNE STREET, -31 9333°S 115 8000°E, GEORGE, R. W., 20-12-58; C31801, PEPPERMINT GROVE ON THE SLOPES, -32 0000°S 115 7667°E, KEIGHTLEY, R., ??-??-??, C31802, COTTESLOE, -32.0000°S 115 7500°E, COLLECTOR UNKNOWN, ??-??-??; C31803, GINGIN, -31 3500°S 115 9167°E, COLLECTOR UNKNOWN, ??-??-??, C31804, PERTH GOVERNMENT GARDENS, -31.9500°S 115.8500°E, NICHOLLS COLLECTION, 05-05-34; C31805, COTTESLOE, -32.0000°S 115 7500°E, DRUMMOND, L., 31-10-25, C31806/7, GIDGEGANNUP WATERFORD ROAD, -31 8500°S 116 1833°E, HARVEY, M. S. & WALDOCK, J. M., 12-02-92, G30; C31808, JOONDALUP EDITH COWAN UNIVERSITY CAMPUS, -31.7550°S 115.7833°E, JUDD, S., ??-03-99, P3; C32258, WOODMAN POINT, -32.1306°S 115.7578°E, HARVEY, M. S. & WALDOCK, J. M., 06-11-95, P3, C32259, WOODMAN POINT, -32 1306°S 115.7578°E, WALDOCK, J. M. & LONGBOTTOM, A. F., 01-09-94, P3, C32260, WOODMAN POINT, -32.1306°S 115 7578°E, HARVEY, M. S. & WALDOCK, J. M., 19-01-95, P3; C32261, WOODMAN POINT, -32 1297°S 115 7564°E, HARVEY, M. S. & WALDOCK, J. M., 06-07-95, P3, C32262, WOODMAN POINT, -32 1297°S 115.7564°E, WALDOCK, J. M. & LONGBOTTOM, A. F., 01-09-94, P3, C32263, WOODMAN POINT, -32 1306°S 115.7578°E, WALDOCK, J. M. & LONGBOTTOM, A. F., 04-11-94, P3, C32264, WOODMAN POINT, -32.1297°S 115.7564°E, HARVEY, M. S. & WALDOCK, J. M., 19-01-95, P3, C32265, WOODMAN POINT, -32 1297°S 115 7564°E, WALDOCK, J. M. & LONGBOTTOM, A. F., 04-11-94, P3, C32266, TUART HILL, -31 8806°S 115 8589°E, WALDOCK, J. M., 07-11-94, P3; C32267, TUART HILL, -31 8806°S 115 8589°E, WALDOCK, J. M., SAMPEY, A. & THORPE, A., 23-09-93, P3; C32268, TUART HILL, -31 8803°S 115 8583°E, WALDOCK, J. M. ET AL., 23-09-93, P3; C32269, TUART HILL, -31 8806°S 115 8589°E, WALDOCK, J. M. ET AL., 18-11-93, P3; C32270, TUART HILL, -31 8803°S 115 8583°E, WALDOCK, J. M., 07-01-94, P3, C32271, TUART HILL, -31 8803°S 115 8583°E, HARVEY, M. S. &

WALDOCK, J. M., 20-07-93, P3; C32272, TUART HILL, -31.8803°S 115.8583°E, COOPER, N., 31-10-93, P2; C32273, TUART HILL, -31.8803°S 115.8583°E, WALDOCK, J. M. ET AL., 18-11-93, P3; C32274, TUART HILL, -31.8806°S 115.8589°E, HARVEY, M. S. & WALDOCK, J. M., 21-03-94, P3; C32275, TUART HILL, -31.8806°S 115.8589°E, HARVEY, M. S. & WALDOCK, J. M., 20-07-93, P3; C32276, TUART HILL, -31.8803°S 115.8583°E, HARVEY, M. S. & WALDOCK, J. M., 21-03-94, P3; C32277, TRIGG DUNE BUSH, -31.8792°S 115.7547°E, HARVEY, M. S. & WALDOCK, J. M., 28-11-95, P3; C32278, TRIGG DUNE BUSH, -31.8792°S 115.7547°E, HARVEY, M. S. & WALDOCK, J. M., 29-01-96, P3; C32279, JANDAKOT AIRPORT, -32.0919°S 115.8744°E, WALDOCK, J. M. & HARVEY, M. S., 21-03-95, P3; C32280, JANDAKOT AIRPORT, -32.0933°S 115.8775°E, WALDOCK, J. M. & HARVEY, M. S., 19-01-95, P3; C32281, HEPBURN HEIGHTS, -31.8186°S 115.7697°E, WALDOCK, J. M. & HARVEY, M. S., 29-01-96, P3; C32282, HEPBURN HEIGHTS, -31.8183°S 115.7672°E, WALDOCK, J. M. & HARVEY, M. S., 25-09-95, P3; C32283, MT CLAREMONT, -31.9611°S 115.7667°E, WALDOCK, J. M. & LONGBOTTOM, A. F., 01-09-94, P3; C32284, MT CLAREMONT, -31.9608°S 115.7656°E, WALDOCK, J. M. & LONGBOTTOM, A. F., 04-11-94, P3; C32285, MT CLAREMONT, -31.9608°S 115.7656°E, WALDOCK, J. M. & HARVEY, M. S., 19-01-95, P3.RVE, -30.9730°S 115.3200°E, JUDD, S., 07-08-98, L70; C30934/5, NILGEN NATURE RESERVE, -30.9730°S 115.3200°E, JUDD, S., 07-08-98; C30936/7, DROVERS CAVE NATIONAL PARK, -30.2530°S 115.0870°E, JUDD, S., 14-10

Diagnosis: Habitus runner. Non-conglobating, introduced species. Body surface without transverse ridges. Body outline interrupted slightly at junction of pereon and pleon.

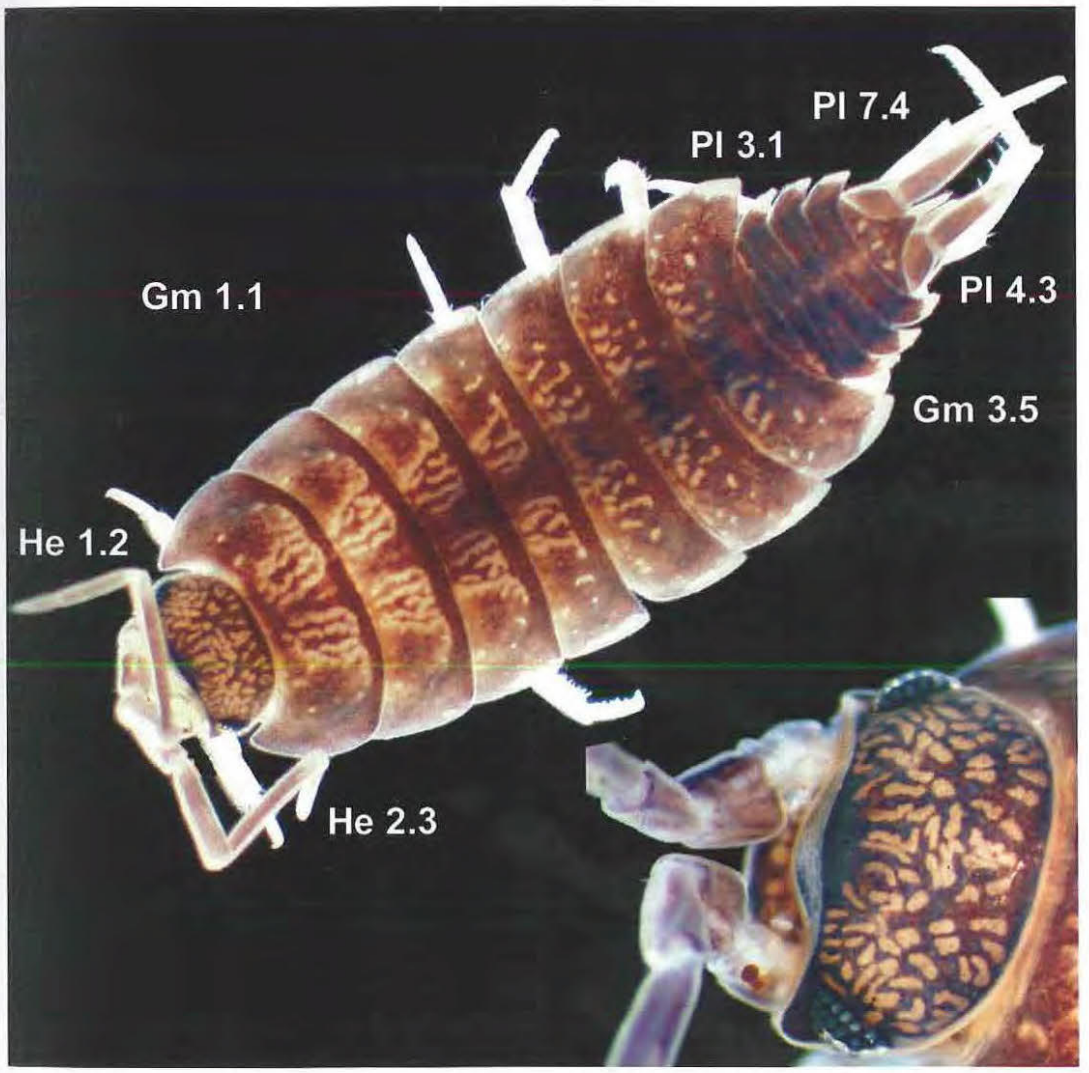


Plate 3.46. Porcellionides pruinosus from Nambung National Park (C30939) (length 9 mm).

3.12.2. GENUS PORCELLIO

MATERIAL EXAMINED BUT DETERMINED ONLY TO GENUS C1680, DANDARAGAN, -30 6667°S 115.7000°E, ??-??-25, C31770, ROTTNEST ISLAND NE SIDE -32 0000°S 115.5000°E, ??? , 13-04-39, R1

3.12.2.1. Porcellio lamellatus Latreille, 1804

Plate 3.10, He 6.1; Plate 3.40, Pl 7.3; Plate 3.47.

Porcellio lamellatus Latreille, 1804

Porcellio lamellatus Bunn & Green, 1982

Porcellio lamellatus Judd & Horwitz, 2003

MATERIAL EXAMINED C12910. ROTTNEST ISLAND 500 M EAST OF ISLET 18, -32 0000°S 115 5000°E, BUNN, S , 06-05-80.

Diagnosis: Habitus runner/creeper. Non-conglobating introduced littoral species. Body outline not interrupted at junction of pleon and pereon. Head with large sub-rectangular central frontal projection and telson sub-triangular with lateral margins only slightly indented.

Remarks: This determination was by A. Green (Bunn & Green, 1982) and their specimens remain the only ones so far collected.

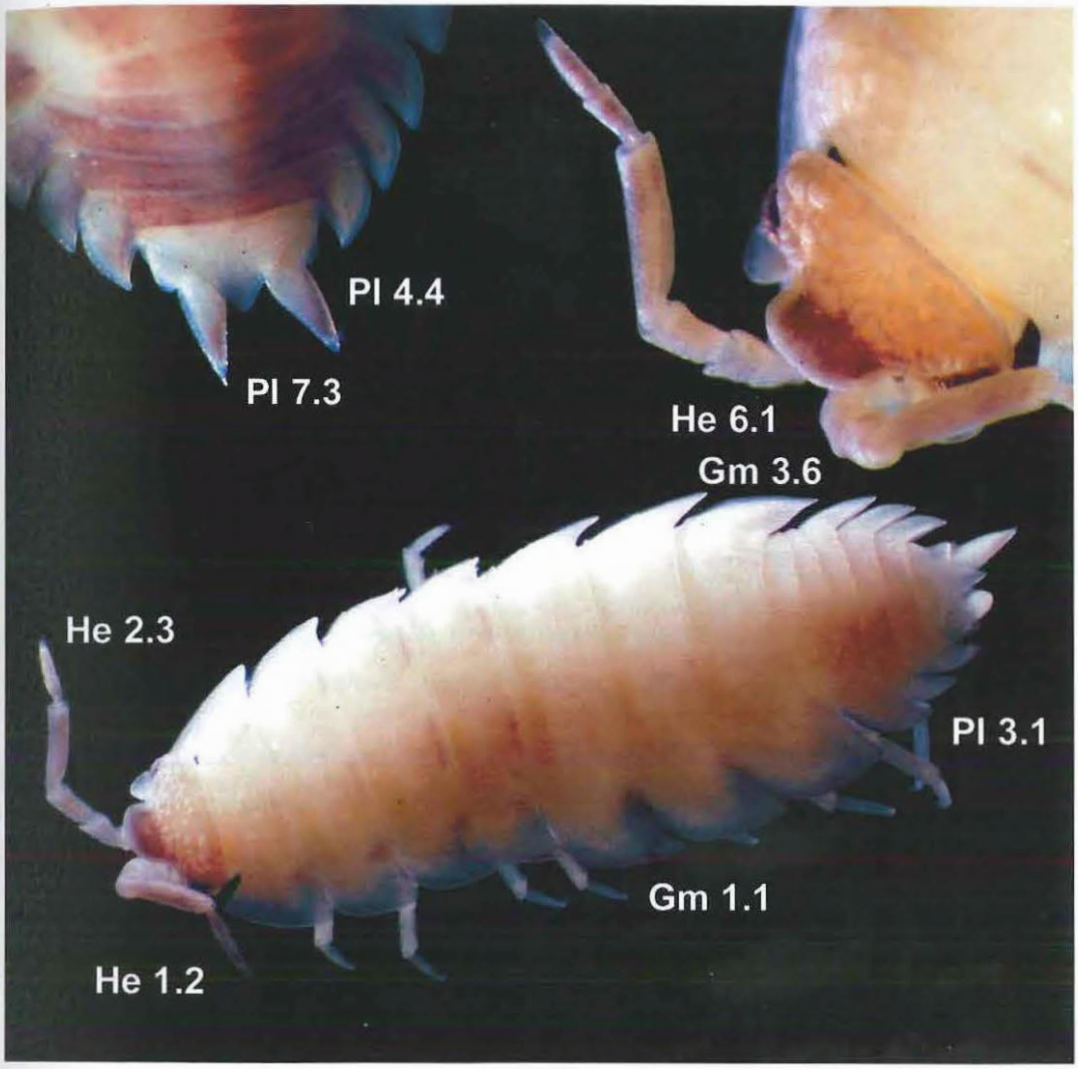


Plate 3.47. Porcellio lamellatus from Rottnest Island (C12910) (length 7 mm)

3.12.2.2. Porcellio scaber Latreille, 1804

Plate 3.6, He 2.3; Plate 3.9, He 5.1; Plate 3.17, Pe 1.2; Plate 3.38, Pl 5.3; Plate 3.40, Pl 7.4; Plate 3.48.

Porcellio scaber Latreille, 1804

Porcellio scaber Budde-Lund, 1912

Porcellio scaber Vandel, 1973

Porcellio scaber Judd & Horwitz, 2003

MATERIAL EXAMINED: C388, ALBANY, COASTAL LAND, -35 0000°S 117.8667°E, HAMBURG EXPEDITION, 13-08-05, C1665, COTTESLOE, -32 0000°S 115 7500°E, GLAUERT, L., ??-??-25; C1666, COTTESLOE, -32 0000°S 115 7500°E, GLAUERT, L., ??-??-25; C2369, PEPPERMINT GROVE PERTH, -32.0000°S 115 7667°E, GLAUERT, L., ??-??-27; C2556/83, GINGIN, -31 3500°S 115 9167°E, GLAUERT, L., ??-??-28; C5195, MANJIMUP, PERUP?, -34.3333°S 116 4500°E, GLAUERT, L., ??-03-36, G30, C12908, NEDLANDS IN GARDEN, -31 9833°S 115 8000°E, BUNN, S., 19-04-80; C18425, SUBIACO, -31 9500°S 115.8667°E, JONES, D S., 17-10-85, C18426, PERTH MUSEUM FLOOR, -31 9500°S 115 8500°E, MCMILLAN, R P., 26-05-87; C18427, SUBIACO, -31.9500°S 115.8167°E, JONES, D S., ??-11-85; C18428, SUBIACO, -31 9500°S 115 8167°E, JONES, D S., 01-10-85, U1, C18429, BROOMEHILL, ALBANY, -33 8500°S 117 6330°E, MCMILLAN, R P., 01-06-87, C19408/9, WEST LEEDERVILLE, -31.9333°S 115 8333°E, HUMPHREYS, W F., 08-06-89, C19544, WEMBLEY GARDEN, -31 9333°S 115 8000°E, JONES, D S., 17-08-89; C19546, MOUNT PLEASANT GARDEN, -32 0333°S 115 8500°E, UNSWORTH, C., 18-07-89, U1, C19555/6, SUBIACO 192 YORK STREET, -31 9500°S 115 8167°E, JONES, D S., ??-10-86, C29711, SUBIACO 192 YORK STREET, -31 9500°S 115.8167°E, JONES, D S., ??-10-86; C30932, MILLBROOK NATURE RESERVE, -34 8550°S 117 8470°E, JUDD, S., 18-12-98, G40, C31771, PERTH, -31.9500°S 115 8500°E, RILEY, G. M., 28-03-63; C31772, DONNYBROOK FONTANINI'S ORCHARD, -33 5833°S 115 8333°E, SPRINGETT, J A., 17-11-71; C31773, CITY BEACH, UNIVERSITY ZOOLOGY DEPARTMENT, -31 9333°S 115 7525°E, SPRINGETT, J A., ??-09-71, C31774, WANNEROO, -31.7550°S 115 8000°E, NAGY, G., 23-05-86, C31775, PERTH WA MUSEUM ON BENCH, -31.9500°S 115 8500°E, RILEY, G M., 17-07-63; C31776, LESMURDIE, -32 0000°S 116 0500°E, CAR, C. A., ??-09-92, P1; C31777, MOUNT PLEASANT, -32 0283°S 115.8467°E, HARVEY, M S., 01-09-91, U1; C31778, COOGEE, -32 1167°S 115 7667°E, TAYLOR, N., 27-06-86, C31779, DENMARK 6 KM W, -34 9667°S 117.3000°E, HARVEY, M. S. & BLOSFELDS, M E., 01-03-89, B10; C31780, ALBANY, W OF ALBANY, -35 0000°S 117 8667°E, NICHOLLS, G E., 31-08-24; C31781, NORNALUP SWARBRICK'S TRACK, -35 0000°S 116.8167°E, NICHOLLS COLLECTION, 02-12-25; C31782, PEMBERTON, -34 4500°S 116.0333°E, NICHOLLS COLLECTION, 11-11-27, G30; C31783, ARTHUR RIVER, -33.3500°S 117.0333°E, CAR, C. A., 15-08-92, B40, C31784, SHENTON PARK SHENTON PARK BUSH, -31 9644°S 115 7992°E, BERRY, P F., ??-11-98, P2, C31785, PERTH, -31 9500°S 115 8500°E, MAJER, J. D., 05-08-87; C32237, TUART HILL, -31.8806°S 115 8589°E, WALDOCK, J. M., 07-11-94, P3, C32238, TUART HILL, -31 8803°S 115 8583°E, HARVEY, M S & WALDOCK, J. M., 19-05-94, P3, C32239, TRIGG DUNE BUSH, -31 8750°S 115.7597°E, HARVEY, M S & WALDOCK, J M., 28-11-95, P3; C32240, MT CLAREMONT, -31 9611°S 115.7667°E, WALDOCK, J M & LONGBOTTOM, A. F., 01-09-94, P3, C32241, MT CLAREMONT, -31.9611°S 115.7667°E, WALDOCK, J. M & HARVEY, M. S., 06-07-95, P3.

Diagnosis: Habitus clinger. Introduced and common synanthropic species. Dorsal surface of head and pereonites tuberculate. Uropod exopodites relatively short and broad. Telson elongate and tapering to point.

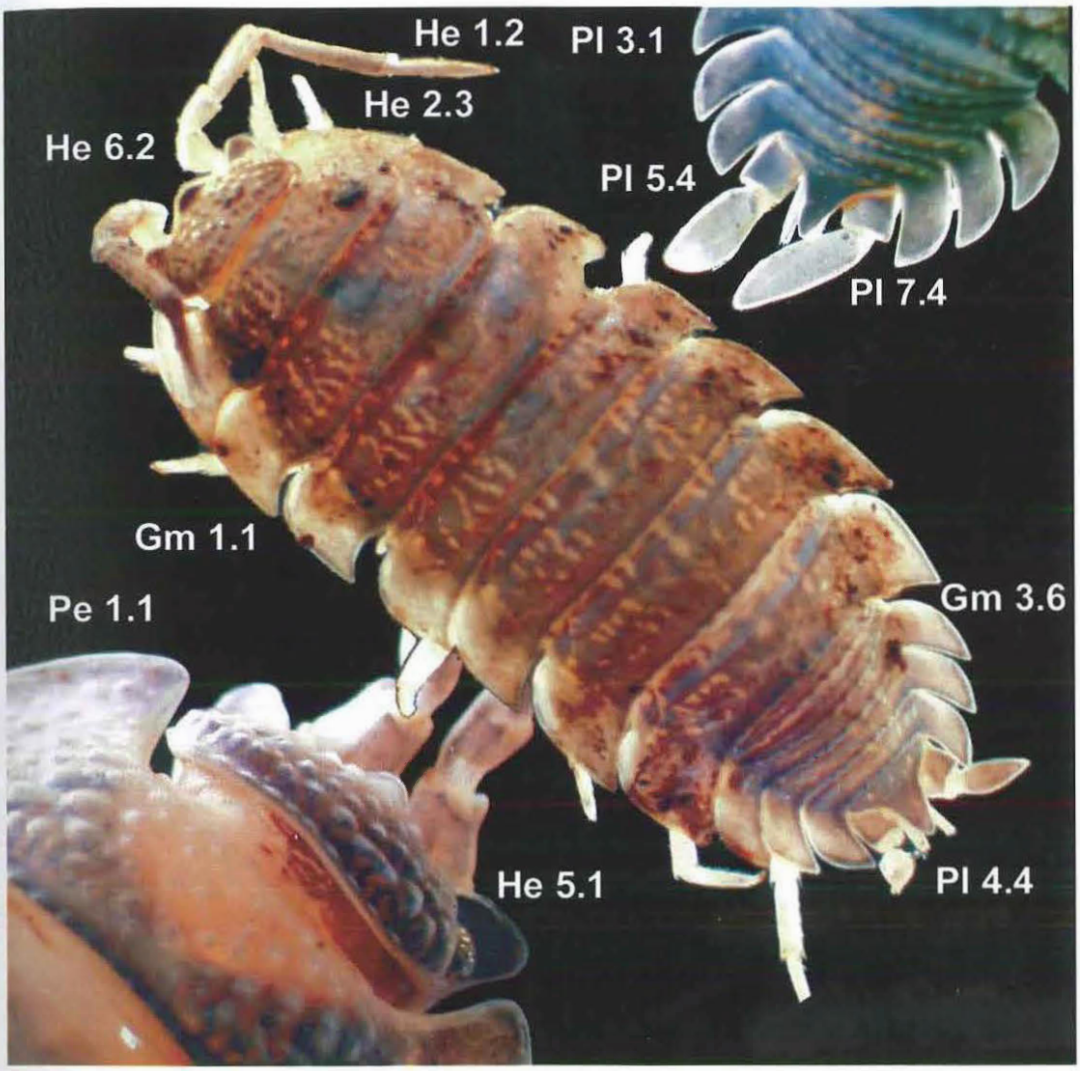


Plate 3.48. Porcellio scaber **from Lesmurdie (C31776) (length 16 mm).**

3.12.2.3. Porcellio laevis Latreille, 1804

Plate 3.3, Gm 3.6; Plate 3.10, He 6.2; Plate 3.38, Pl 5.4; Plate 3.49.

Porcellio laevis Latreille, 1804

Porcellio laevis Budde-Lund 1912

Porcellio laevis Wahrberg 1922

Porcellio laevis Vandel, 1973

Porcellio laevis Judd & Horwitz, 2003

MATERIAL EXAMINED C381, FREMANTLE, -32 0667*S 115 7500*E, HAMBURG EXPEDITION, 05-05-05; C782, PERTH, -31 9500*S 115 8500*E, ROCKLIFE, W , 02-10-22, C1556/67, LAKE MONGER WARRIEDAL STREET, -31 9333*S 115 8333*E, COLLECTOR UNKNOWN, 29-09-24; C1921, SUBIACO, -31.9500*S 115 8167*E, OHL, ??-11-26; C2081/2, ROTTNEST ISLAND LAKE HERSCHELL SOUTH SHORE, -32 0000*S 115 5000*E, GLAUERT, L , ??-??-27; C2844, ROTTNEST ISLAND SERPENTINE LAKE, -32 0000*S 115 5000*E, GLAUERT, L , ??-??-28, C11021, NEDLANDS UNIVERSITY OF WA GARDEN SOIL, -31 9833*S 115 8000*E, SPRINGETT, J A , 15-09-71, U1, C12909, NEDLANDS, -31 9833*S 115 8000*E, BUNN, S., 19-04-80, U1, C31786, COMO OR CITY BEACH PERTH METRO, -31.9500*S 115 8500*E, SPRINGETT, J A., ??-08-72, C31787, CITY BEACH, UNIVERSITY ZOOLOGY DEPARTMENT TILTON TERRACE, -31 9333*S 115 7525*E, SPRINGETT, J A., ??-10-71; C31788, WANNEROO, -31.7550*S 115 8000*E, NAGY, G , 23-05-86, C31789, KELMSCOTT CLIFTON HILLS, -32 1333*S 116 0000*E, NICHOLLS COLLECTION, 05-12-77, C31790/1, MOUNT PLEASANT, -32 0283*S 115 8467*E, HARVEY, M. S , 01-09-91, U1; C31792, FLOREAT PARK, -31 9333*S 115 7833*E, COLLECTOR UNKNOWN, 16-04-65; C31793, NEDLANDS, -31 9833*S 115 8000*E, KOCH, L E , ??-??-??, C31794, PERTH GOVERNMENT GARDENS, -31.9500*S 115.8500*E, WAMMERSLEY, MR , 05-05-32, C31795, NEDLANDS UNIVERSITY OF WESTERN AUSTRALIA GROUNDS, -31 9833*S 115 8000*E, SWAN & DRUMMOND, ??-07-29; C31796, PERTH GARDEN VIA BPS, -31 9500*S 115 8500*E, SPRINGETT, J A , ??-10-71; C31797, COTTESLOE, -32.0000*S 115.7500*E, COLLECTOR UNKNOWN, ??-??-??; C31798, QUINNS ROCK WATTLE PARK, -31 6667*S 115 7000*E, QUINNS ROCK ENVIRONMENTAL GROUP, 11-10-94, P2, C32242, TUART HILL, -31.8806*S 115 8589*E, WALDOCK, J M , 07-11-94, P3, C32243, TUART HILL, -31 8806*S 115 8594*E, WALDOCK, J. M., 07-11-94, P3; C32244, TUART HILL, -31 8806*S 115.8589*E, WALDOCK, J M., SAMPEY, A. & THORPE, A., 23-09-93, P3, C32245, TUART HILL, -31 8803*S 115 8583*E, WALDOCK, J. M. ET AL., 23-09-93, P3; C32246, TUART HILL, -31 8806*S 115 8589*E, WALDOCK, J. M. ET AL , 18-11-93, P3; C32247, TUART HILL, -31 8803*S 115 8583*E, WALDOCK, J M , 07-01-94, P3, C32248, TUART HILL, -31 8803*S 115 8583*E, HARVEY, M S. & WALDOCK, J M , 20-07-93, P3, C32249, TUART HILL, -31 8803*S 115 8583*E, COOPER, N., 31-10-93, P2; C32250, TUART HILL, -31 8803*S 115 8583*E, WALDOCK, J M ET AL., 18-11-93, P3, C32251, TUART HILL, -31.8806*S 115.8589*E, HARVEY, M S. & WALDOCK, J M., 20-07-93, P3, C32252, TRIGG DUNE BUSH, -31 8750*S 115 7597*E, HARVEY, M S & WALDOCK, J M , 25-09-95, P3; C32253, PERTH AIRPORT, -31.9761*S 115 9736*E, WALDOCK, J. M., GOODSELL, J. & WEBB, J., 06-01-94, P3; C32254, MT CLAREMONT, -31.9611*S 115.7667*E, HOW, R., 28-11-94, P2; C32255, MT CLAREMONT, -31 9611*S 115 7667*E, WALDOCK, J M & LONGBOTTOM, A F., 04-11-94, P3; C32256, MT CLAREMONT, -31 9608*S 115 7656*E, HOW, R , 31-10-94, P2, C32257, TUART HILL, -31 8803*S 115 8583*E, WALDOCK, J M , 07-01-94, P3

Diagnosis: Habitus clinger. Introduced and very common synanthropic species. Dorsal surface entirely smooth, uropod exopodites relatively long and tapering, widest at end nearest body. Telson elongate and tapering to point.

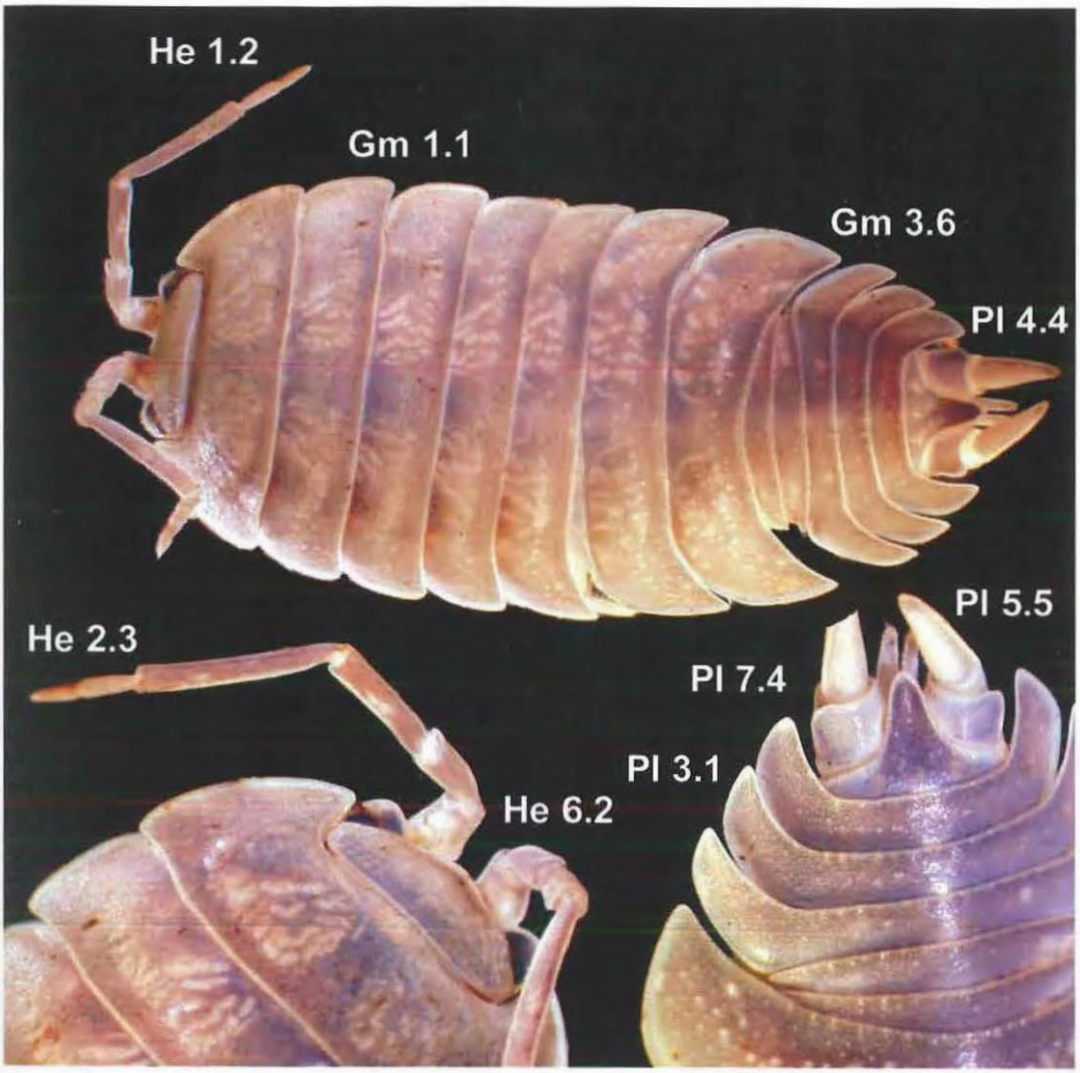


Plate 3.49. Porcellio laevis from Mount Claremont (C32256) (length 13 mm).

3.13. FAMILY STYLONISCIDAE VANDEL

Diagnosis: Non-conglobating. Flagellum of antenna 2 with 4-10 articles distinctly conical shaped with a tuft of setae at apex. Mandible with molar process. Eyes composed of 3 ommatidia (in all species described here) but may be reduced or absent. Without pleopodal lungs in pleopod exopodites. Body convex, shallowly convex or dorso-ventrally flattened. Pereonites without noduli laterales. Telson trapezoidal.

3.13.1. GENUS NOTONISCUS CHILTON

Green (1961, p.286) gave a full diagnosis of the genus. The principal determining charactenstics are the relatively convex central portion of the pereon, bearing sculptured ridges, and the almost horizontal and discontiguous pereonal epimera. The body outline is not, or is only slightly, interrupted at the junction of the pereon and pleon. Pleonal epimeron may be either small or well developed while epimera 4 & 5 are well developed.

3.13.1.1. Notoniscus new species

Plate 3.3, Gm 3.7; Plate 3.8, He 4.2; Plate 3.17, Pe 1.2; Plate 3.24, Pe 8.1; Plate 3.50.

Notoniscus sp. nov. Judd & Horwitz, 2003

MATERIAL EXAMINED: C29794, BIG BROOK DAM FOREST, -34.4050°S, 116.0270°E, JUDD, S., 15-08-98, B10, C31044, PEMBERTON HV64 MARRI RD, -34.5000°S, 116.0000°E, SPRINGETT, J. A., 03-12-71, C31045, PEMBERTON HV64 MARRI RD, -34.5000°S, 116.0833°E, SPRINGETT, J. A., 03-12-71, C31046, KARRI VALLEY RESORT, -34.4333°S, 115.8500°E, WALDOCK, J. M., 21-10-97, L41

Diagnosis. Habitus clinger. Pleonal epimera 4 and 5 extended therefore body outline not interrupted at junction of pereon and pleon. Head with prominent sculpturing and well developed lateral lobes. Pereonites with very prominent longitudinal rows of raised bumps. Pereonal epimera discontiguous and projecting laterally.

Remarks: This species is distinct from the other species of Notoniscus known from Australia. It differs from N. tasmanicus in the respect that, like N. chiltoni, it lacks well developed epimera of pleonite 3. It displays a similar general morphology to N. chiltoni but differs in many respects, principally in the dorsal features of the head and the shape and degree of development of pleonal epimera 4 & 5. Green (1971) provided descriptions of Tasmanian species.

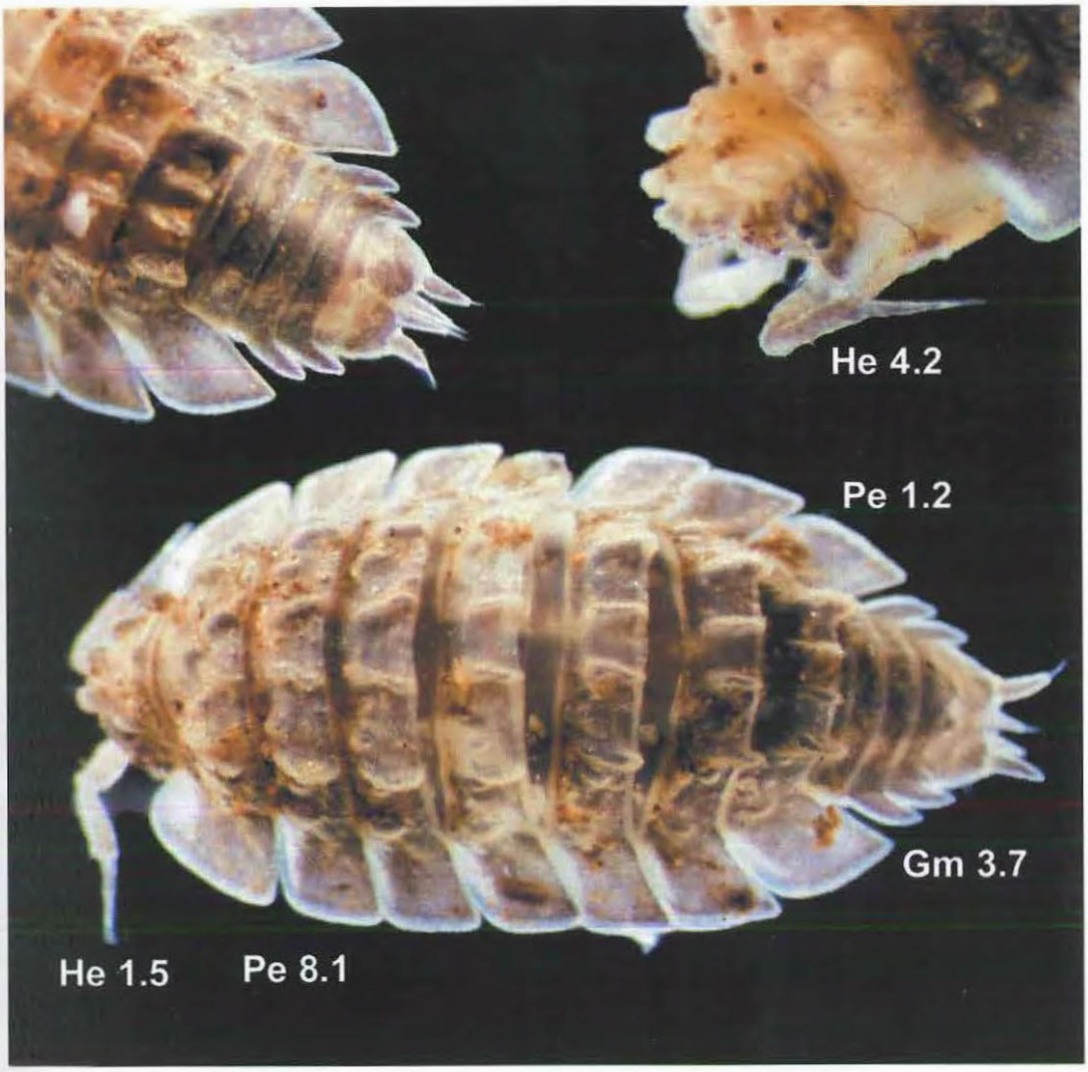


Plate 3.50. Notoniscus new species from the Pemberton area (C31046) (length 4 mm)

3. .3.2. STYLONISCUS DANA

MATERIAL EXAMINED BUT DETERMINED ONLY TO GENUS: C21078, MT COOKE, -32 4167°S 116 3000°E, WALDOCK, J M, 28-12-91, P3, C29792, WALPOLE NORNALUP NATIONAL PARK TINGLEWOOD, -35 0030°S 116 6380°E, JUDD, S, 07-01-99, G20, C29793, WALPOLE NORNALUP NATIONAL PARK SAPPER'S BRIDGE, -34 9600°S 116 8220°E, JUDD, S, 10-01-99, L10, C31022, GLENEAGLE BO68 HAVEL'S PLOT 171, -32 2500°S 116 1667°E, SPRINGETT, J A., 22-10-71, C31023, LAKE GWELUP, -31 8667°S 115 7667°E, WALDOCK, J M, 28-05-88, L60, C31024, LEDGE POINT, -35 0167°S 118 0000°E, HUMPHREYS, W F ET AL, 20-03-85, C31025, PORONGURUPS, -34 6667°S 117 8333°E, BOWLEY, E A, 20-04-35, C31026, ARMADALE, -32 1500°S 116 0000°E, NICHOLLS COLLECTION, ??-05-34, C31027, GLENEAGLE BL68 HAVEL'S PLOT 166, -32 2500°S 116 1667°E, SPRINGETT, J A, 18-10-71, C31028, MANJIMUP GY55 GRAY PINE CREEK RD, -34 2500°S 116 0000°E, SPRINGETT, J A, 08-11-71, C31029, PEMBERTON HV64 MARRI RD, -34 5000°S 116 0833°E, SPRINGETT, J A, 03-12-71, C31030, TWO PEOPLES BAY TICK FLAT MET STATION, -34 9833°S 118 1667°E, SPRINGETT, J A, 12-04-71, C31031, TRIGG NEAR WEST COAST H'WAY, -31 8667°S 115 7530°E, WALDOCK, J M, 18-12-93, P3, C31032, NORNALUP, -35 0000°S 116 8167°E, DOUGLAS, A M, 18-07-92, L41, C31033, DARRADUP 3 KM WEST, -34 0833°S 115 5667°E, BANNISTER, J, 14-10-91, L60, C31034, SHANNON NATIONAL PARK 3 KM N OF DOG POOL, -34 7500°S 116 4000°E, HARVEY, M S & WALDOCK, J M, 24-03-93, L10, C31035, SHANNON NATIONAL PARK DOG POOL ON SHANNON RIVER 3 KM N, -34 7500°S 116 3667°E, HARVEY, M S & WALDOCK, J M, 30-04-90, R2, C31036, TORNDIRRUP NATIONAL PARK GULLY OUTSIDE N EDGE ON LIMEBURNERS RD, -35 0833°S 117 9000°E, HARVEY, M S & WALDOCK, J M, 26-03-93, B10, C31037, SWARBRICK'S TRACK VIA ALBANY, -35 0000°S 116 8167°E, NICHOLLS COLLECTION, 03-01-33, C31038, DEEP RIVER, -35 0000°S 116 6667°E, NICHOLLS COLLECTION, 31-12-32, C31039, WALPOLE CAMP SITE, -34 9833°S 116 7167°E, NICHOLLS COLLECTION, 12-01-33, C31040, NORNALUP INLET, -35 0000°S 116 7167°E, NICHOLLS COLLECTION, 20-11-25, L10, C31041, 4 75 KM ESE OF MARGARET RIVER, -33 9644°S 115 1228°E, PETERSON, M, 14-02-92, C31042, STIRLING RANGE NATIONAL PARK WEST END OF ELLEN TRACK, -34 3844°S 118 2881°E, HARVEY, M S ET AL, 04-09-96, P3, C31043, MT CHUDALUP REEDIA SWAMP SHRUBLAND, -34 7664°S 116 0811°E, HORWITZ, P ET AL, ??-10-94, A30, C31833, MT HENRY, -32 0314°S 115 8622°E, WALDOCK, J M & LONGBOTTOM, A F, 04-11-94, P3

Remarks. The genus is very distinctive and a full generic diagnosis was given by Green (1961, p 269) Size may be up to 14 mm but most species are of a very small size (~ 3 mm). Eyes are composed of 3 ommatidia. . Species listed below are determined as Stylonıscus because they are very similar to species of Stylonıscus described from Tasmania and New Zealand. However, it should be noted that the genenc diagnosis ıncludes characters of the mandıbles, genital apophysis and male pleopods 1 that require confirmation by dissection and further examination.

3.13.2.1. Stylonicus species 1

Plate 3 8, He 4.3; Plate 3 11, He 7.3; Plate 3.24, Pe 8.2; Plate 3.51.

Tnchonicus thomsoni Wahrberg, 1922

Stylonicus otakensis Vandel 1973

Stylonicus australiensis australiensis Vandel, 1973

Stylonicus sp.1 Judd & Horwitz, 2003

MATERIAL EXAMINED C11023, PEMBERTON HV61, -34 5000°S 116 0000°E, SPRINGETT, J A , 09-11-71, C18441, BYFORD, MONDJEAL, -32 2170°S 116 0000°E, MCMILLAN, R. P , 10-07-88, C21077, DARRADUP 3 KM WEST, -34 0833°S 115 5667°E, BANNISTER, J , 10-11-91, L10, C29801/3, LEONA ROAD, -32 2180°S 116 3250°E, JUDD, S , 23-07-98, L10, C29804, MANARING LAKE, -31 8750°S 116 3250°E, JUDD, S , 23-07-98, L10, C29805, KARNET BROOK, -32 4070°S 116 0270°E, JUDD, S , 29-07-98, L10, C29806/7, SCARP ROAD NEAR NORTH DANDALUP, -32 5600°S 116 0050°E, JUDD, S , 29-07-98, L10, C29808/10, SCARP ROAD NEAR NORTH DANDALUP, -32 5600°S 116 0050°E, JUDD, S , 29-07-98, L20, C29811, WELLINGTON MILL, -33 4430°S 115 9080°E, JUDD, S , 30-07-98, L10, C29812, MT LENNARD, -33 3920°S 115 8870°E, JUDD S , 30-07-98, L10, C29813, JOHN FOREST NATIONAL PARK JANE BROOK, -31 8850°S 116 0900°E, JUDD, S , 11-08-98, L30, C29814/15, JOHN FOREST NATIONAL PARK (SCARP), -31 8900°S 116 0870°E, JUDD, S , 11-08-98, L10, C29816, WARREN NATIONAL PARK, PETTICOAT LANE, -34 5070°S 115 9130°E, JUDD, S , 13-08-98, L0C , 29817, WARREN NATIONAL PARK, PETTICOAT LANE, -34 5070°S 115 9130°E, JUDD, S , 13-08-98, L20, C29818, WARREN NATIONAL PARK, PETTICOAT LANE, -34 5070°S 115 9130°E, JUDD, S , 13-08-98, L10, C29819, WARREN NATIONAL PARK TREAN BROOK, -34 4820°S 115 9250°E, JUDD, S , 13-08-98, L10; C29820, WARREN NATIONAL PARK TREAN BROOK, -34 4820°S 115 9250°E, JUDD, S , 13-08-98, L20, C29821, WARREN NATIONAL PARK TREAN BROOK, -34 4820°S 115 9250°E, JUDD, S , 13-08-98, B10, C29822, WARREN NATIONAL PARK TREAN BROOK, -34 4820°S 115 9250°E, JUDD, S , 13-08-98, L10, C29823, BIG BROOK DAM FOREST, -34 4050°S 116.0270°E, JUDD, S , 15-08-98, L20, C29824/5, WALYUNGA NATIONAL PARK, -31 7320°S 116 0730°E, JUDD, S , 21-08-98, G40, C29826/7, WALYUNGA NATIONAL PARK, -31 7320°S 116 0730°E, JUDD, S , 21-08-98, L10, C29828, WALYUNGA NATIONAL PARK, -31 7320°S 116 0730°E, JUDD, S , 21-08-98, R1, C29829/30, CANNING RIVER (BELOW CANNING DAM), -32 1430°S 116 1100°E, JUDD, S , 25-08-98, L30; C29831, CANNING RIVER (BELOW CANNING DAM), -32 1430°S 116 1100°E, JUDD, S , 25-08-98, G10, C29832/33, CANNING RIVER (BELOW CANNING DAM), -32 1430°S 116 1100°E, JUDD, S , 25-08-98, L30, C29834/6, JULIMAR CONSERVATION PARK, -31 3950°S 116 2950°E, JUDD, S , 09-10-98, L42, C29837, MOGANMOGANNING NATURE RESERVE, -31 1200°S 116 2530°E, JUDD, S , 11-10-98, L42, C29838/9, YANCHEP NATIONAL PARK, -31 5200°S 115 6630°E, JUDD, S , 13-10-98, L10, C29840, LUPTON CONSERVATION PARK NORTH, -32 4470°S 116 6430°E, JUDD, S , 26-10-98, L10, C29841, SCHULSTAAD ROAD CREEK, -32 2800°S 116 3600°E, JUDD, S , 05-11-98, L10, C29842, HARRIS DAM, -33 2550°S 116 1150°E, JUDD, S , 30-10-98, L10, C29843, HARRIS DAM, -33 2550°S 116 1150°E, JUDD, S , 30-10-98, L20, C29844, OCCIDENTAL FOREST BLOCK DALE ROAD, -32 1050°S 116 2570°E, JUDD, S , 04-11-98, L10, C29845, OCCIDENTAL FOREST BLOCK DALE ROAD, -32 1050°S 116 2570°E, JUDD, S , 04-11-98, L20, C29846, OCCIDENTAL FOREST BLOCK DALE ROAD, -32 1050°S 116 2570°E, JUDD, S , 04-11-98, G30, C29847/8, MONADNOCKS CONSERVATION PARK MARGINATA ROAD, -32 2420°S 116 2050°E, JUDD, S , 04-11-98, L20, C29849/50, MONADNOCKS CONSERVATION PARK MARGINATA ROAD, -32 2420°S 116 2050°E, JUDD, S , 04-11-98, L10, C29851, MONADNOCKS CONSERVATION PARK MILLARS LOG ROAD, -32 3950°S 116 3350°E, JUDD, S , 05-11-98, L10, C29852, MONADNOCKS CONSERVATION PARK MILLARS LOG ROAD, -32 3950°S 116 3350°E, JUDD, S , 05-11-98, L40; C29853, SCHULSTAAD ROAD CREEK, -32 2800°S 116 3600°E, JUDD, S , 05-11-98, G30, C29854, KEN ROAD STATE FOREST, -32 5320°S 116 2850°E, JUDD, S , 06-11-98, L20, C29855, WHITE HORSE HILL, -32 6070°S 116 2950°E, JUDD, S , 06-11-98, L10, C29856, AMPHION FOREST BLOCK, -32 7920°S 116 1870°E, JUDD, S , 10-11-98, L20, C29857/8, AMPHION FOREST BLOCK, -32 7920°S 116 1870°E, JUDD, S , 10-11-98, L10, C29859, LEPERS GULLY ROAD, -32 8470°S 115 1080°E, JUDD, S , 10-11-98, L10, C29860, LEPERS GULLY ROAD, -32 8470°S 116 1080°E, JUDD, S , 10-11-98, L20, C29861, LEPERS GULLY ROAD, -32 8470°S 116 1080°E, JUDD, S , 10-11-98, L10, C29862, PINDALUP ROAD/ N E ROAD, -32 6000°S 116 2000°E, JUDD, S , 11-11-98, G20, C29863/4, NOGGERUP CONSERVATION PARK, -33 6220°S 116 1230°E, JUDD, S , 24-11-98, L20, C29865, PRESTON CONSERVATION PARK, -33 6030°S 116 0630°E, JUDD, S , 24-11-98, L20, C29866, PRESTON CONSERVATION PARK, -33 6030°S 116 0630°E, JUDD, S , 24-11-98, L10, C29867, PRESTON CONSERVATION PARK, -33 6030°S 116 0630°E, JUDD, S , 24-11-98, G20, C29868, BENGER SWAMP NATURE RESERVE, -33 1780°S 115 8330°E, JUDD, S , 25-11-98, L10, C29869, CHALK BROOK (LANE POOLE RESERVE), -33 0670°S 116 2320°E, JUDD, S , 26-11-98, B40, C29870, CHALK BROOK (LANE POOLE RESERVE), -33 0670°S 116 2320°E, JUDD, S , 26-11-98, L10, C29871, CHALK BROOK (LANE POOLE RESERVE), -33 0670°S 116 2320°E, JUDD, S , 26-11-98, G20, C29872, JOES ROAD, -33 7300°S 115 7530°E, JUDD, S , 30-11-98, L10, C29873, BRIDCETOWN WEST NATURE RESERVE, -33 9520°S 116 0780°E, JUDD, S , 01-12-98, L10, C29874, BRIDGETOWN JARRAH PARK, -34 0300°S 115 9830°E, JUDD, S , 01-12-98 L20, C29875, BRIDGETOWN JARRAH PARK, -34 0300°S 115 9830°E, JUDD, S , 01-12-98, L40, C29876, BRIDGETOWN JARRAH PARK, -34 0300°S 115 9830°E, JUDD, S , 01-12-98, G20, C29877/8, MILYEANNUP CONSERVATION PARK?, -34 0900°S 115 5670°E, JUDD, S , 02-12-98, L10, C29879, MILYEANNUP CONSERVATION PARK?, -34 0900°S 115 5670°E, JUDD, S , 02-12-98, G40, C29880, MILYEANNUP CONSERVATION PARK?, -34 0900°S 115 5670°E, JUDD, S , 02-12-98, G20, C29881/3, ST JOHNS CONSERVATION PARK, -33 9450°S 115 6900°E, JUDD, S , 02-12-98, L10, C29884, ELLIS CREEK ROAD, -33 9350°S 115 8820°E, JUDD, S , 03-12-98, L10, C29885, ELLIS CREEK ROAD, -

33 9350"S 115 8820"E, JUDD, S , 03-12-98, G40, C29886, ELLIS CREEK ROAD, -33 9350"S 115 8820"E, JUDD, S , 03-12-98, L20, C29887, MULLALYUP CONSERVATION PARK, -33 7150"S 115 8680"E, JUDD, S , 03-12-98, L30, C29888/9, SPEARWOOD CREEK, -34 0920"S 115 3130"E, JUDD, S , 08-12-98, L10, C29890, SPEARWOOD CREEK, -34 0920"S 115 3130"E, JUDD, S , 08-12-98, L20, C29891, SPEARWOOD CREEK, -34 0920"S 115 3130"E, JUDD, S , 08-12-98, G20, C29892, MARGARET RIVER CREEK, -33 9350"S 115 0650"E, JUDD, S , 10-12-98, L10, C29893, MARGARET RIVER CREEK, -33 9350"S 115 0650"E, JUDD, S , 10-12-98, G20, C29894, MARGARET RIVER CREEK, -33 9350"S 115 0650"E, JUDD, S , 10-12-98, B40, C29895, WAYCHINICUP NATIONAL PARK, -34 8800"S 118 3270"E, JUDD, S , 19-12-98, L30, C29896, WALPOLE NORNALUP NATIONAL PARK TINGLEWOOD, -35 0030"S 116 6380"E, JUDD, S , 07-01-99, L40, C29897, WALPOLE NORNALUP NATIONAL PARK TINGLEWOOD, -35 0030"S 116 6380"E, JUDD, S , 07-01-99, G20, C29898/900, ORDNANCE STATE FOREST, -34 8680"S 116 6650"E, JUDD, S , 10-01-99, L10, C29901, WALPOLE NORNALUP NATIONAL PARK, -34 9880"S 116 7600"E, JUDD, S , 11-01-99, L10, C29902, WALPOLE NORNALUP NATIONAL PARK, -34 9880"S 116 7600"E, JUDD, S , 11-01-99, G40, C29903, WALPOLE NORNALUP NATIONAL PARK, -34 9880"S 116 7600"E, JUDD, S , 11-01-99, G20, C29904, SHANNON NATIONAL PARK (FISH CREEK ROAD), -34 6250"S 116 4370"E, JUDD, S , 27-01-99, L10, C29905, SHANNON NATIONAL PARK (FISH CREEK ROAD), -34 6250"S 116 4370"E, JUDD, S , 27-01-99, L20, C29906, SHANNON NATIONAL PARK (FISH CREEK ROAD), -34 6250"S 116 4370"E, JUDD, S , 27-01-99, G20, C29907, SHANNON RIVER/CHESAPEAKE RD , -34 8420"S 116 3700"E, JUDD, S , 27-01-99, L10, C29908, BOMBAKUP STATE FOREST, -34 6080"S 116 0320"E, JUDD, S , 28-01-99, L10, C29909, BOMBAKUP STATE FOREST, -34 6080"S 116 0320"E, JUDD, S , 28-01-99, L41, C29910, MT CHUDALUP, -34 7630"S 116 0830"E, JUDD, S , 28-01-99, L41, C29911, MT CHUDALUP, -34 7630"S 116 0830"E, JUDD, S , 28-01-99, L10, C29912/15, MOUNT DALE, -32 1259"S 116 2951"E, WATSON, A , 01-10-01, P3, C29916/18, MOUNT DALE, -32 1259"S 116 2951"E, JUDD, S & WATSON, A., 26-06-01, G10, C29919/20, MOUNT DALE, -32 1137"S 116 2898"E, WATSON, A , 01-10-01, P3, C29921, MOUNT DALE, -32 1011"S 116 2875"E, JUDD, S & WATSON, A., 14-10-01, G10, C29922/29928, MOUNT DALE, -32 0899"S 116 2961"E, WATSON, A , 01-10-01, P3, C29929/30, MOUNT DALE, -32 0899"S 116 2961"E, JUDD, S & WATSON, A , ??-??-01, G10, C29931/32, MOUNT DALE, -32 1193"S 116 2912"E, WATSON, A , 01-10-01, P3, C29933/34, MOUNT DALE, -32 1028"S 116 2861"E, WATSON, A , 01-10-01, P3, C29935/29938, MOUNT DALE, -32 1028"S 116 2861"E, JUDD, S & WATSON, A , 26-06-01, G10, C29939/29941, MOUNT DALE, -32 0918"S 116 2779"E, WATSON, A , 01-10-01, P3, C29942/46, MOUNT DALE, -32 0918"S 116 2779"E, JUDD, S & WATSON, A , 26-06-01, G10, C29947, MOUNT DALE, -32 0878"S 116 2784"E, WATSON, A , 01-10-01, P3, C29948/56, MOUNT DALE, -32 0878"S 116 2784"E, JUDD, S & WATSON, A , 11-10-01, G10, C2995763, MOUNT DALE, -32 0834"S 116 2831"E, WATSON, A , 01-10-01, P3, C29964/67, MOUNT DALE, -32 0834"S 116 2831"E, JUDD, S & WATSON, A , ??-06-01, G10, C29968/79, MOUNT DALE, -32 0834"S 116 2831"E, JUDD, S & WATSON, A , 14-12-01, G10, C29980, MOUNT DALE, -32 0940"S 116 2804"E, WATSON, A , 01-10-01, P3, C29981/2, MOUNT DALE, -32 0885"S 116 2810"E, WATSON, A , 01-10-01, P3, C29983/7, MOUNT DALE, -32 0885"S 116 2810"E, JUDD, S & WATSON, A , 21-06-01, G10, C29988, MOUNT DALE, -32 0885"S 116 2810"E, JUDD, S & WATSON, A , 11-10-01, G10, C29989, MOUNT DALE, -32 0992"S 116 2851"E, WATSON, A , 01-10-01, P3; C29990, MOUNT DALE, -32 0869"S 116 2928"E, WATSON, A , 01-10-01, P3, C31050, GLENEAGLE BL67 HAVEL'S PLOT 169, -32 2500"S 116 1667"E, SPRINGETT, J A , 18-10-71, C31051, PEMBERTON HV61, -34 5000"S 116 0000"E, SPRINGETT, J A , 09-11-71, C31052, MANJIMUP, -34 2500"S 116 2500"E, SPRINGETT, J. A , 14-04-71, C31053, PEMBERTON HV64 MARRI RD, -34 5000"S 116 0833"E, SPRINGETT, J A , 03-12-71, C31054, NORNALUP, -35 0000"S 116 8167"E, NICHOLLS COLLECTION, ??-??-38, C31055, DARLINGTON, -31 9167"S 116 0667"E, NICHOLLS COLLECTION, 01-07-35, C31056, PEMBERTON HL62 BIG BROOK 12, -34 2667"S 115 9333"E, SPRINGETT, J A , 15-11-71, C31057, PEMBERTON HV64 MARRI RD, -34 5000"S 116 0833"E, SPRINGETT, J A , 03-12-71, C31058, PEMBERTON HV61, -34 5000"S 116 0000"E, SPRINGETT, J A , 08-11-71, C31059, PEMBERTON HV64 MARRI RD, -34 5000"S 116 0000"E, SPRINGETT, J A , 03-12-71; C31060, PEMBERTON HV64 MARRI RD, -34 5000"S 116 0833"E, SPRINGETT, J A , 22-07-70, C31061, TWO PEOPLES BAY TICK FLAT MET STAT GULLY, -34 9833"S 118 1667"E, SPRINGETT, J A , 22-05-70, C31062, PEMBERTON HV64 MARRI RD, -34 5000"S 116 0833"E, SPRINGETT, J A , 03-12-71, C31063, GLENEAGLE BO68, -32 2500"S 116 1667"E, SPRINGETT, J A , 18-10-71, C31064, PEMBERTON HU61, -34 5000"S 116 0000"E, SPRINGETT, J A , 09-11-71, C31065, PEMBERTON HV64 MARRI RD, -34 5000"S 116 4167"E, SPRINGETT, J A , 21-07-70, C31066, PEMBERTON-VASSE, -34 4500"S 116 0333"E, SPRINGETT, J A , 23-09-71, B10, C31067, GLENEAGLE BO68 HAVEL'S PLOT 171, -32 2500"S 116 1667"E, SPRINGETT, J A , 22-10-71, S1, C31068, FRANKLAND RIVER, -35 0000"S 116 8167"E, NICHOLLS COLLECTION, 02-12-25, G30, C31069, LITTLE DANDALUP CREEK DEL PARK RD CROSSING, -32 6000"S 115 9833"E, FRIEND, J A , 31-05-81, C31070, MT COOKE, -32 4167"S 116 3000"E, HARVEY, M S & WALDOCK, J M , 31-07-91, P3, C31071, BASE OF MOUNT COOKE, -32 4167"S 116 3000"E, HARVEY, M S , WALDOCK, J M & PETERSON, M , 07-08-90, 3772/3, MT COOKE, -32 4167"S 116 3000"E, HARVEY, M S & WALDOCK, J M , 19-09-91, P3, C31074, MT COOKE, -32 4167"S 116 3000"E, HARVEY M S & WALDOCK, J M , 15-05-91, P3, C31075, MT COOKE, -32 4167"S 116 3000"E, HARVEY, M S & WALDOCK, J M , 16-06-91, P3, C31076, MT COOKE, -32 4167"S 116 3000"E, HARVEY, M S & WALDOCK, J M., 15-05-91, P3, C31077, NINDUP W OF WITCHCLIFFE, -34 0500"S 115 0500"E, WALDOCK, J M , 06-02-93, L41, C31078 YORK 10 KM SW, -31 9500"S 116 5167"E, BANNISTER, J , 15-08-93, L10, C31079, SHANNON NATIONAL PARK DOG POOL ON SHANNON RIVER, -34 7667"S 116 3667"E, HARVEY, M S & WALDOCK, J M , 30-04-90, C31080, WOOROLOO NEAR CREEK, -31 8000"S 116 3000"E, COLLECTOR UNKNOWN, 20-08-32, C31081, SWARBRICK'S TRACK VIA ALBANY, -35 0000"S 116 8167"E, NICHOLLS COLLECTION, 04-01-33, C31082, FRANKLAND RIVER, -35 0000"S 116 8167"E, NICHOLLS COLLECTION, 11-01-33, C31083, DWELLINGUP NANGA STUDY SITES, -32 7667"S 116 0833"E, JUDD, S , ??-03-97, G10, C31084/6, WALPOLE NORNALUP NATIONAL PARK, -34 9833"S 116 7167"E, WALLIS, N , ??-??-91, C31087, KARRI VALLEY RESORT, -34 4333"S 115 8500"E, WALDOCK, J M , 21-10-97, L41, C31088, STIRLING RANGE NATIONAL PARK SOUTH FACE OF PYONGURUP? PEAK, -34 3714"S 118 3222"E, HARVEY, M S ET AL , 04-09-96, P3, C31089, WALPOLE NORNALUP NATIONAL PARK KARRI FOREST, -35 0000"S 116 7167"E, VAN HEURCK, P ET AL , 13-05-97, L10, C31090, WALPOLE NORNALUP NATIONAL PARK KARRI FOREST, -34 9833"S 116 7083"E, VAN HEURCK, P ET AL , 13-05-97, L40, C31091, WALPOLE NORNALUP NATIONAL PARK KARRI FOREST, -34 9833"S 116 7083"E, VAN HEURCK, P ET AL , 13-05-97, G30,

C31092, WALPOLE NORNALUP NATIONAL PARK TINGLE UPLAND FOREST, -34.9917°S 116.6500°E, VAN HEURCK, P. ET AL., 20-05-97, L10; C31093, WALPOLE NORNALUP NATIONAL PARK TINGLE CREEK FOREST, -34.9583°S 116.8000°E, VAN HEURCK, P. ET AL., 14-05-97, L40; C31094, WALPOLE NORNALUP NATIONAL PARK TINGLE CREEK FOREST, -34.9750°S 116.7917°E, VAN HEURCK, P. ET AL., 14-05-97, G30; C31095, WALPOLE NORNALUP NATIONAL PARK TINGLE CREEK FOREST, -34.9750°S 116.7833°E, VAN HEURCK, P. ET AL., 16-05-97, L10; C31096, KARRI VALLEY RESORT, -34.4333°S 115.8500°E, WALDOCK, J. M., 21-10-97, L41; C31834, BRICKWOOD RESERVE, CARDUP, -32.2311°S 116.0033°E, WALDOCK, J. M., WEST, P. L. & LONGBOTTOM, A., 17-06-96, P3; C31835, TALBOT ROAD RESERVE, -31.8736°S 116.0508°E, WALDOCK, J. M. & HARVEY, M. S., 24-06-93, P3; C31836, TALBOT ROAD RESERVE, -31.8733°S 116.0478°E, WALDOCK, J. M. ET AL., 23-09-93, P3.

Diagnosis: Habitus runner. Body outline interrupted at junction of pereon and pleon. Head with poorly developed lateral lobes. Head and pereonites smooth with numerous and sparsely distributed setae. Animal convex without horizontal projection of pereonal epimera.

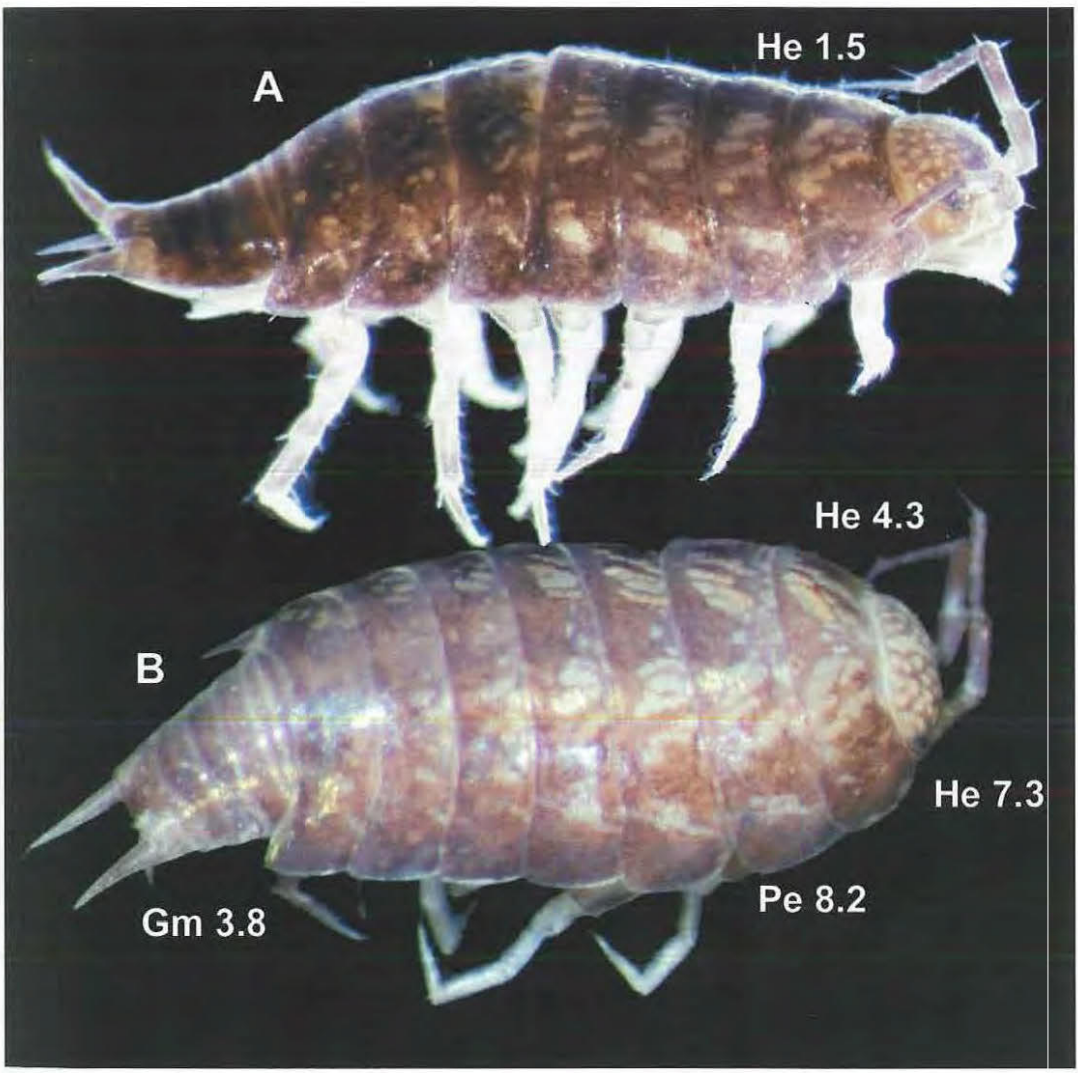


Plate 3.51. Styloniscus species 1 (A) from Shannon National Park (C29906) (length 3 mm) and (B) jarrah forest at Scarp Road near North Dandalup (C29807) (length 3.5 mm).

3.13.2.2. Styloniscus species 2

Plate 3.7, He 3.1; Plate 3.52.

?Trichoniscus verrucosus Wahrberg, 1922

MATERIAL EXAMINED: C30048, WANNAMAL LAKES NATURE RESERVE, -31.0750°S 116.0470°E, JUDD, S., 11-10-98, R1; C30049, MOORAPULLING NATURE RESERVE, -32.9020°S 116.5730°E, JUDD, S., 28-10-98, G30; C30050, JINGALUP NATURE RESERVE, -34.0130°S 117.0130°E, JUDD, S., 29-10-98, L42.

Diagnosis: Habitus creeper. Animal very small (~ 3 mm), long and thin. Body outline interrupted only slightly at junction of pereon and pleon. Dorsal surface densely setose and/or irregularly bumpy. Distal articles 4 & 5 of peduncle of antennae 2 short and very broad.

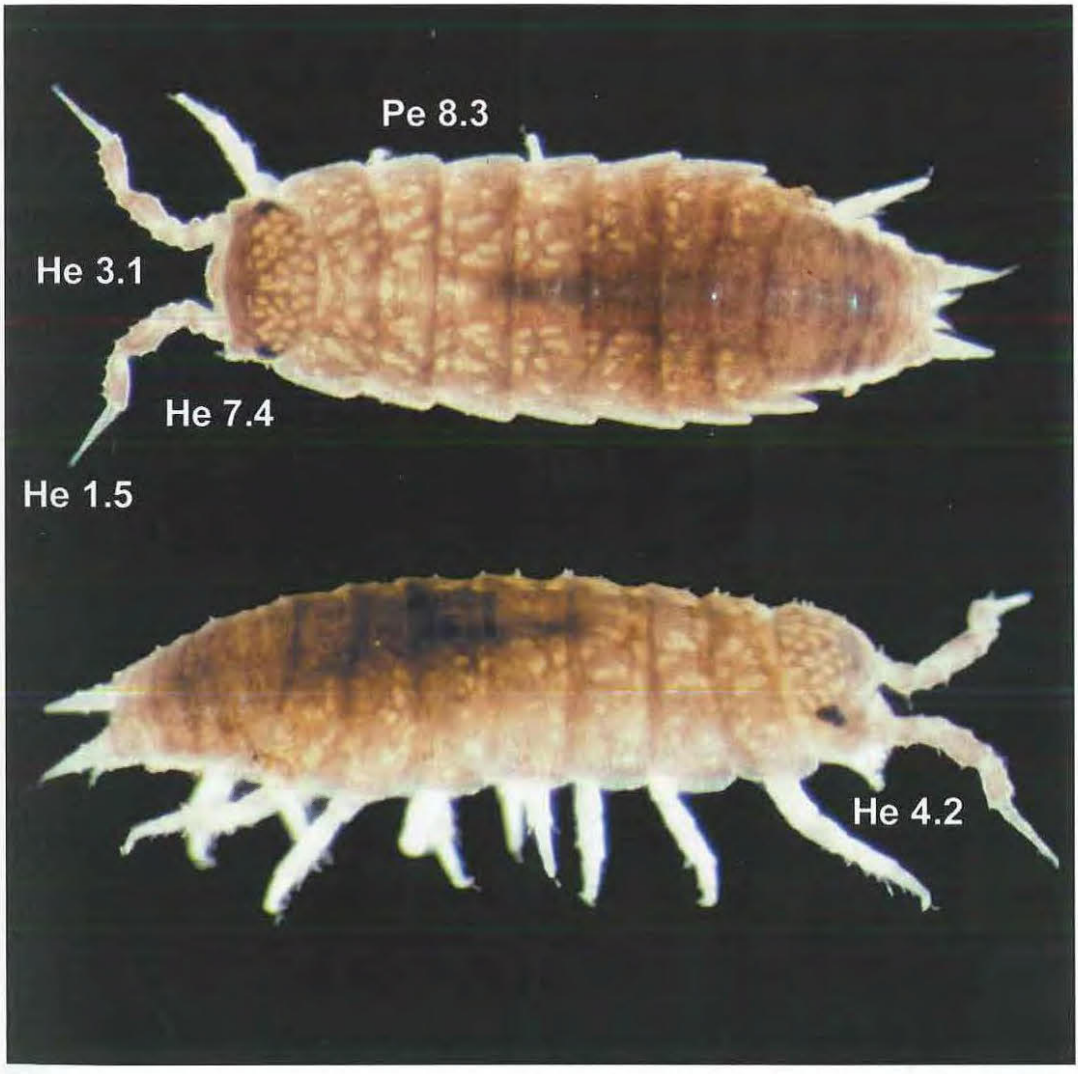


Plate 3.52. Styloniscus species 2 from Wannamal Lakes Nature Reserve (C30048) (length 1.5 mm).

3.13.2.3. Styloniscus species 3

Plate 3.3, Gm 3.8; Plate 3.9, He 5.3; Plate 3.18, Pe 2.2; Plate 3.24, Pe 8.3; Plate 3.53.

MATERIAL EXAMINED: C29797/8, WALPOLE NORNALUP NATIONAL PARK, -34.9880°S 116.7600°E, JUDD, S., 11-01-99, L10; C29799, BOMBAKUP STATE FOREST, -34.6080°S 116.0320°E, JUDD, S., 28-01-99, L10; C31047, WALPOLE INLET CAMP SITE, -34.9833°S 116.7333°E, NICHOLLS COLLECTION, 12-01-33; C31048, FRANKLAND RIVER, -35.0000°S 116.8167°E, NICHOLLS COLLECTION, 04-01-33; C31049, SWARBRICK'S TRACK VIA ALBANY, -35.0000°S 116.8167°E, NICHOLLS COLLECTION, ??-04-33.

Diagnosis: Habitus clinger. Animal flatter with pereonal epimera moderately or well extended laterally. Body outline interrupted at junction of pereon and pleon. Pereonal epimera appearing only slightly separated in dorsal view. Pereonites 1, 2 & 3 with bumps arranged in longitudinal rows usually more evident close to longitudinal midline. Head bumpy but without prominent sculpturing and with prominent lateral lobes. Distal articles 4 & 5 of peduncle of antennae 2 not short and broad.

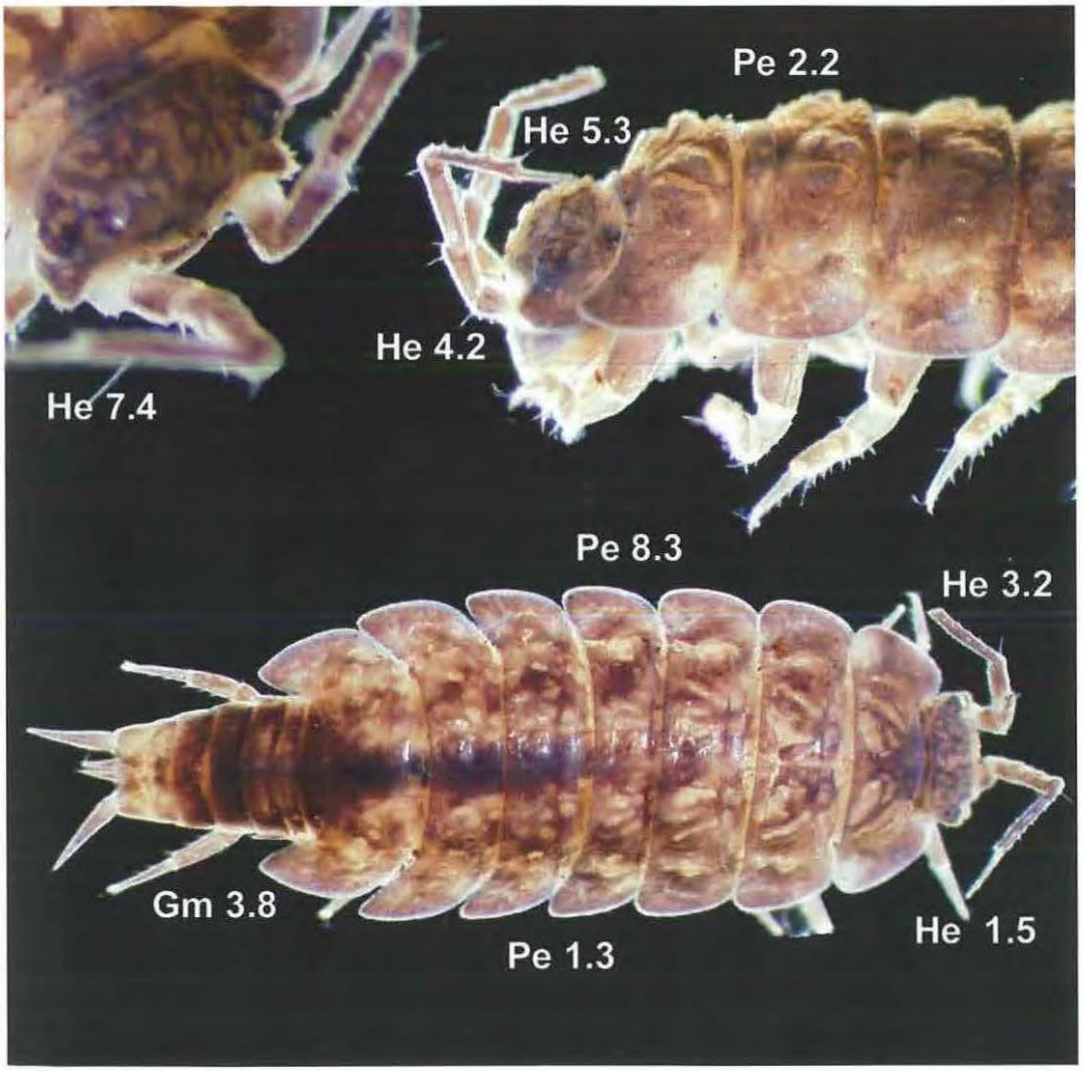


Plate 3.53. Styloniscus species 3 from Walpole Nornalup National Park (C29797) (length 5 mm).

3.13.2.4. Styloniscus species 4

Plate 3.4, Gm 3.4; Plate 3.8, He 4.3; Plate 3.9, He 5.2; Plate 3.17, Pe 1.3; Plate 3.18, Pe 2.1; Plate 3.18, Pe 2.4; Plate 3.54.

MATERIAL EXAMINED: C29796, DUNSBOROUGH CNR. COMMONAGE/WILDWOOD RDS, -33.6920°S 115.0670°E, JUDD, S., 15-07-98, L10.

Diagnosis: Habitus clinger. Animal broad and flat with pereonal epimera moderately or well extended laterally. Head very bumpy with prominent lateral lobes. Body outline interrupted at junction of pereon and pleon. Pereonal epimera appearing only slightly separated in dorsal view. Prominent longitudinal rows of bumps on pereonites 1, 2 & 3.

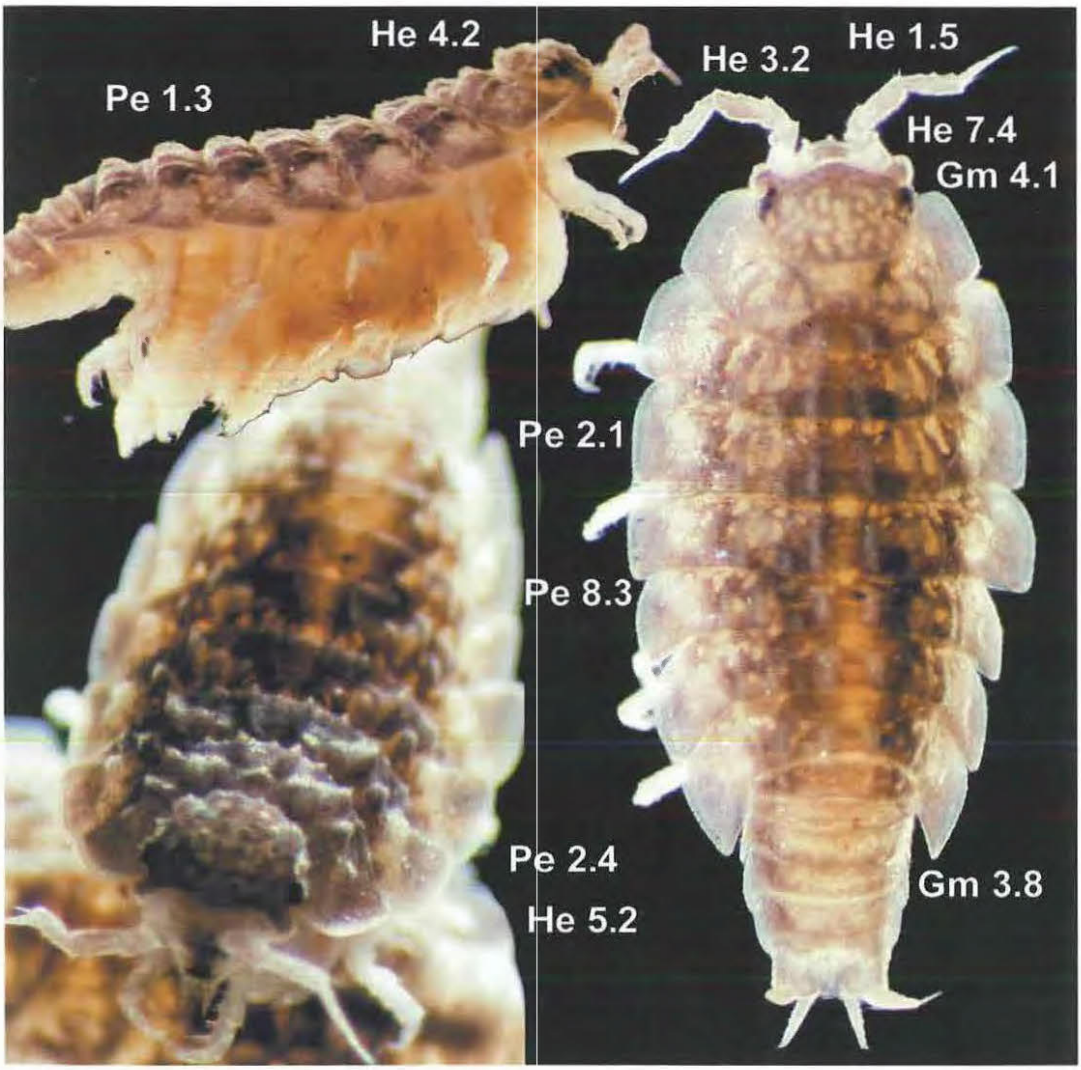


Plate 3.54. Styloniscus species 4 from private property near Dunsborough (C29796) (length 3 mm).

3.13.2.5. Styloniscus species 5

Plate 3.4, Gm 4.2; Plate 3.18, Pe 2.5; Plate 3.55

MATERIAL EXAMINED: C29795, WALYUNGA NATIONAL PARK, -31.7320°S 116.0730°E, JUDD, S., 21-08-98, L10.

Diagnosis: Habitus clinger. Body outline interrupted at junction of pereon and pleon. Animal slender and flat with longitudinal rows of bumps on pereonites 1, 2 & 3 present but not prominent. Pereonal epimera appearing well separated in dorsal view. Head bumpy with prominent lateral lobes.

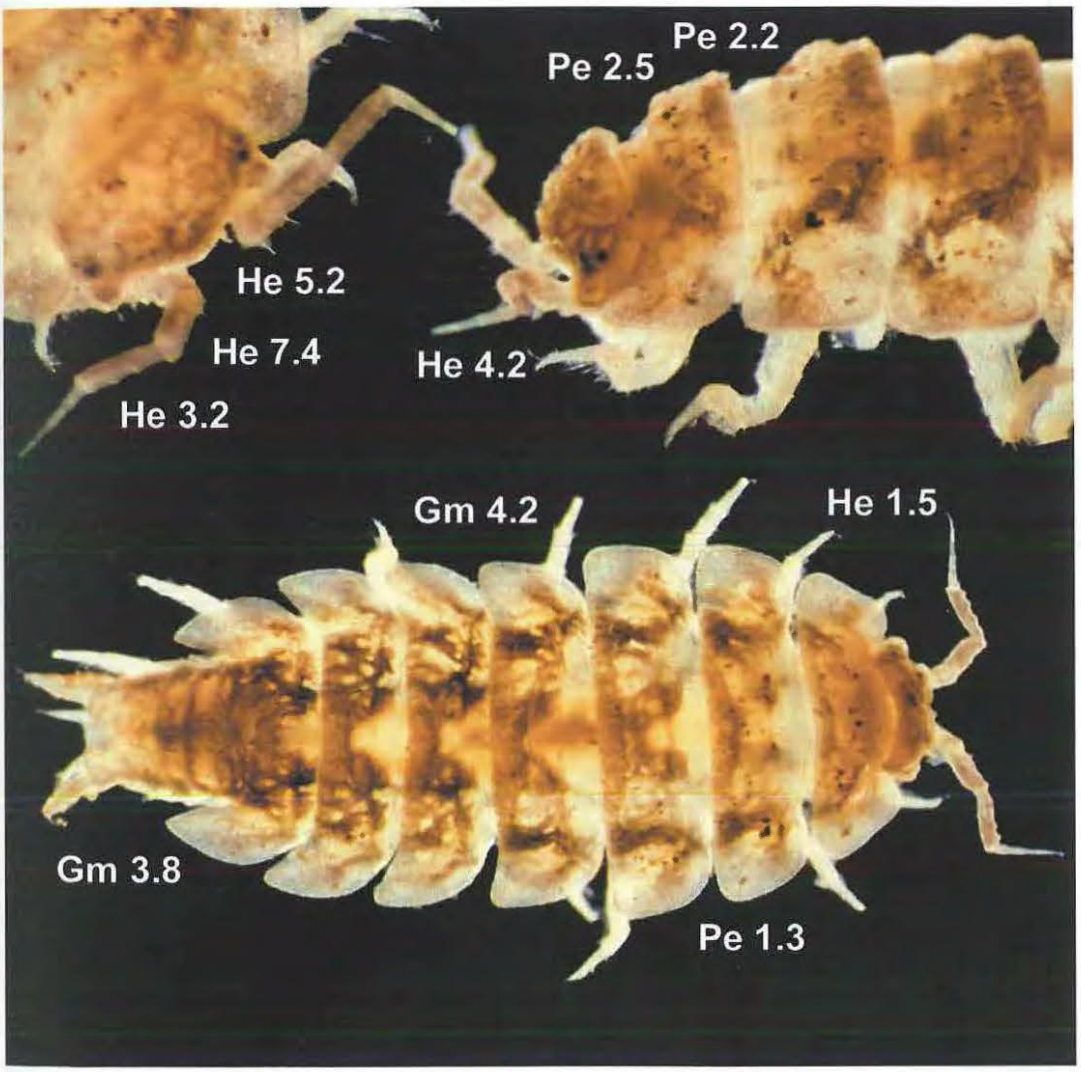


Plate 3.55. Styloniscus species 5 from Walyunga National Park (C29795) (length 4 mm).

3.13.2.6. Styloniscus species 6

Plate 3.2, Gm 2.2; Plate 3.7, He 3.2; Plate 3.17, Pe 1.4, Plate 3.56

MATERIAL EXAMINED: C30051, CANNING RIVER (BELOW CANNING DAM), -32.1430°S 116.1100°E, JUDD, S., 25-08-98, G30; C30052, MILYEANNUP CONSERVATION PARK?, -34.0900°S 115.5670°E, JUDD, S., 02-12-98, G20.

Diagnosis: Habitus creeper. Animal white, long and slender with body outline interrupted at junction of pereon and pleon. Head with moderately developed lateral lobes. Pereonites with well defined tubercles in rows parallel with, and close to, posterior margin of each pereonite. Animal very flat with pereonal epimera slightly separated in dorsal view.

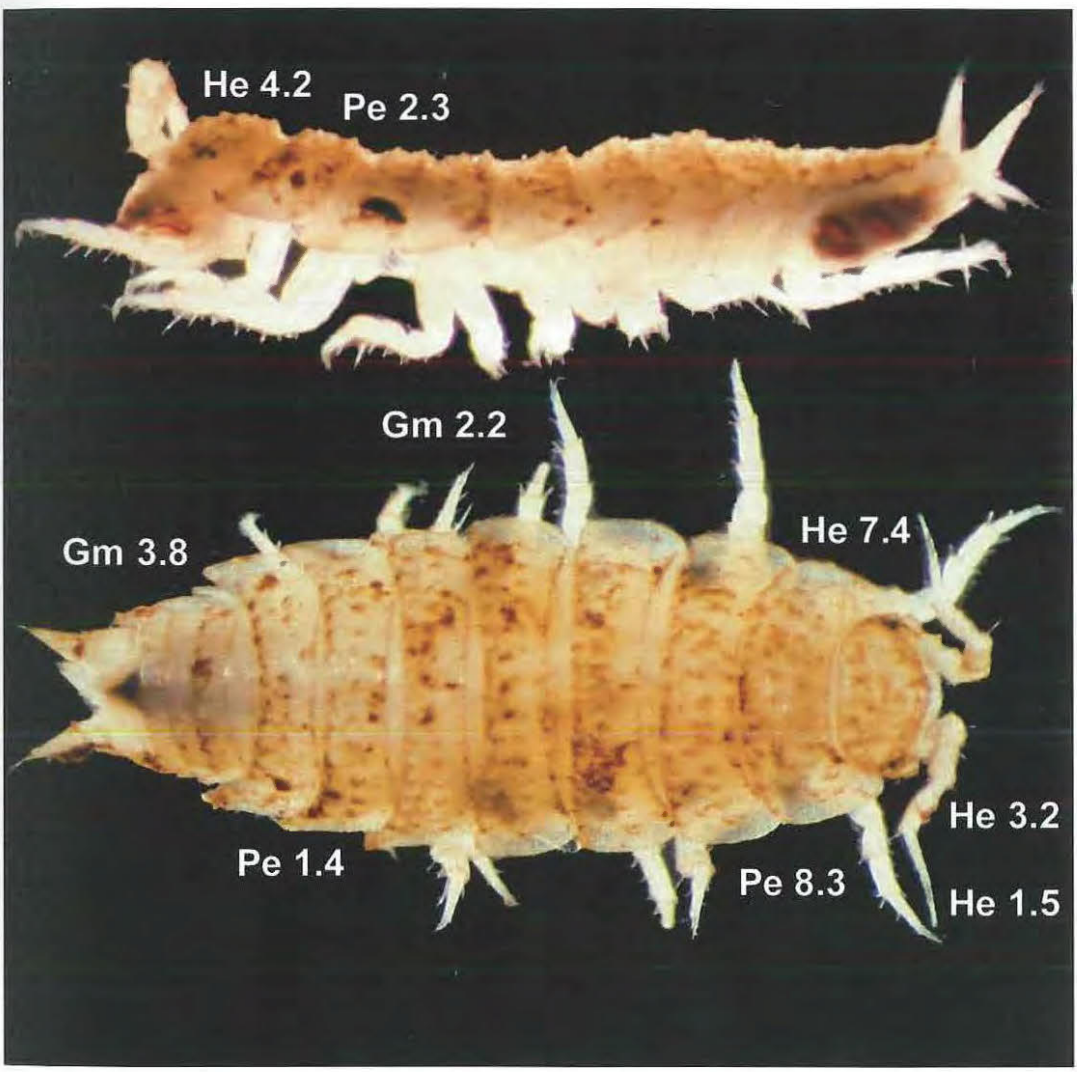


Plate 3.56. Styloniscus species 6 from Milyeannup Conservation Park (C30052) (length 4 mm).

3.13.2.7. Styloniscus species 7

Plate 3 2, Gm 2 3, Plate 3 5, He 1 5, Plate 3 6, He 3.3, Plate 3.11, He 7 4; Plate 3 17, Pe 1 5, Plate 3 17, Pe 1 6; Plate 3.18, Pe 2 3; Plate 3.57a, 3.57b

Trichoniscus otakensis Wahrberg, 1922

Styloniscus sp 2 Judd & Horwitz, 2003

MATERIAL EXAMINED C29704, STRONG'S CAVE, -34 1500'S 115 0333'E, HOWLETT, R., 29-01-61, S1, C29991 MT LINDESAY (WEST SIDE), -34 8630'S 117 3160'E, JUDD, S., 08-01-99, L20, C29992, DUNSBOROUGH CNR COMMONAGE/WILDWOOD RDS, -33 6920'S 115 0670'E, JUDD, S., 15-07-98, G20, C29993, MT LENNARD, -33 3920'S 115 8870'E, JUDD, S., 30-07-98, L10, C29994, WARREN NATIONAL PARK, PETTICOAT LANE, -34 5070'S 115 9130'E, JUDD, S., 13-08-98, L41, C29995, WARREN NATIONAL PARK TREAN BROOK, -34 4820'S 115 9250'E, JUDD, S., 13-08-98, L20, C29996, WARREN NATIONAL PARK TREAN BROOK, -34 4820'S 115 9250'E, JUDD, S., 13-08-98, B10, C29997/8, WARREN NATIONAL PARK TREAN BROOK, -34 4820'S 115 9250'E, JUDD, S., 13-08-98, G20, C29999, WARREN NATIONAL PARK TREAN BROOK, -34 4820'S 115 9250'E, JUDD, S., 13-08-98, L41, C30000, CLEAVE ROAD OFF SCOTT RD, -34 4180'S 115 7930'E, JUDD, S., 14-08-98, L60, C30001, CLEAVE ROAD OFF SCOTT RD, -34 4180'S 115 7930'E, JUDD, S., 14-08-98, L20, C30002, CLEAVE ROAD OFF SCOTT RD, -34 4180'S 115 7930'E, JUDD, S., 14-08-98, G50, C30003, BIG BROOK DAM FOREST, -34 4050'S 116 0270'E, JUDD, S., 15-08-98, B10, C30004, BIG BROOK DAM FOREST, -34 4050'S 116 0270'E, JUDD, S., 15-08-98, G40, C30005, YORNUP BLOCK UPPER DONNELLY RIVER, -34 0980'S 116 1580'E, JUDD, S., 15-08-98, G40, C30006, CANNING RIVER (BELOW CANNING DAM), -32 1430'S 116 1100'E, JUDD, S., 25-08-98, G10, C30007, HADDLETON NATURE RESERVE, -33 6330'S 116 5980'E, JUDD, S., 29-10-98, L40, C30008, BOOLADING NATURE RESERVE, -33 3500'S 116 6270'E JUDD, S., 30-10-98, L41, C30009, PROPOSED LANE POOLE EXTENSION, -33 2030'S 116 4630'E, JUDD, S., 30-10-98, L10, C30010, HARRIS DAM, -33 2550'S 116 1150'E, JUDD, S., 30-10-98, L10, C30011, HARRIS DAM, -33 2550'S 116 1150'E, JUDD, S., 30-10-98, L20, C30012, NOGGERUP CONSERVATION PARK, -33 6220'S 116 1230'E, JUDD, S., 24-11-98, L20, C30013, PRESTON CONSERVATION PARK, -33 6030'S 116 0630'E, JUDD, S., 24-11-98, G20, C30014, LESCHENAULT CONSERVATION PARK, -33 2250'S 115 6920'E, JUDD, S., 25-11-98, L10, C30015, BRIDGETOWN WEST NATURE RESERVE, -33 9520'S 116 0780'E, JUDD, S., 01-12-98, L10, C30016, MILYEANNUP CONSERVATION PARK?, -34 0900'S 115 5670'E, JUDD, S., 02-12-98, G40, C30017, MILYEANNUP CONSERVATION PARK?, -34 0900'S 115 5670'E, JUDD, S., 02-12-98, G20, C30018, ELLIS CREEK ROAD, -33 9350'S 115 8820'E, JUDD, S., 03-12-98, L10, C30019/20, SPEARWOOD CREEK, -34 0920'S 115 3130'E, JUDD, S., 08-12-98, L10, C30021, SPEARWOOD CREEK, -34 0920'S 115 3130'E, JUDD, S., 08-12-98, G20, C30022/23, GINGILUP SWAMPS NATURE RESERVE, -34 3320'S 115 4400'E, JUDD, S., 09-12-98, L20, C30024/25, GINGILUP SWAMPS NATURE RESERVE, -34 3320'S 115 4400'E, JUDD, S., 09-12-98, G40, C30026, LEEUWIN NATURALISTE NATIONAL PARK KARRI NEAR HAMELIN BAY, -34 2000'S 115 0720'E, JUDD, S., 10-12-98, L10, C30027, PORONGORUP NATIONAL PARK BOLGANUP DAM, -34 6700'S 117 8820'E, JUDD, S., 16-12-98, L41, C30028, PORONGORUP NATIONAL PARK BOLGANUP DAM, -34 6700'S 117 8820'E, JUDD, S., 16-12-98, L10, C30029, WEST CAPE HOWE NATIONAL PARK, -35 0820'S 117 6430'E, JUDD, S., 17-12-98, G20, C30030, TORNDIRRUP NATIONAL PARK, -35 1150'S 117 9330'E, JUDD, S., 18-12-98, L10, C30031, RATE BLOCK, -34 8350'S 117 0070'E, JUDD, S., 09-01-99, L10, C30032, RATE BLOCK, -34 8350'S 117 0070'E, JUDD, S., 09-01-99, L41 C30033/34, ORDNANCE STATE FOREST, -34 8680'S 116 6650'E, JUDD, S., 10-01-99, G20, C30035, MOUNT FRANKLAND NATIONAL PARK CROSSING BLOCK, -34 8030'S 116 8830'E, JUDD, S., 10-01-99, B40, C30036, WALPOLE NORNALUP NATIONAL PARK, -34 9880'S 116 7600'E, JUDD, S., 11-01-99, L10, C30037, WALPOLE NORNALUP NATIONAL PARK, -34 9880'S 116 7600'E, JUDD, S., 11-01-99, G40, C30038, WALPOLE NORNALUP NATIONAL PARK, -34 9880'S 116 7600'E, JUDD, S., 11-01-99, G20, C30039, LONG/THOMPSON BLOCK, -34 6600'S 116 7030'E, JUDD, S., 11-01-99, L10, C30040, SHANNON NATIONAL PARK (FISH CREEK ROAD), -34 6250'S 118 4370'E, JUDD, S., 27-01-99, L10, C30041, SHANNON NATIONAL PARK (FISH CREEK ROAD), -34 6250'S 116 4370'E, JUDD, S., 27-01-99, B10, C30042, SHANNON NATIONAL PARK (FISH CREEK ROAD), -34 6250'S 116 4370'E, JUDD, S., 27-01-99, G20, C30043, SHANNON RIVER/CHESAPEAKE RD, -34 8420'S 116 3700'E, JUDD, S., 27-01-99, L10, C30044/45, BOMBAKUP STATE FOREST, -34 6080'S 116 0320'E, JUDD, S., 28-01-99, L10, C30046, BOMBAKUP STATE FOREST, -34 6080'S 116 0320'E, JUDD, S., 28-01-99, G20, C30047, MT CHUDALUP, -34 7630'S 116 0830'E, JUDD, S., 28-01-99, L10, C31097, PEMBERTON HV64 MARRI RD, -34 5000'S 116 0833'E, SPRINGETT, J. A., 03-12-71, C31098, APPLECROSS, -32 0167'S 115 8333'E, NORRIS, K. R., 01-07-34, C31099 APPLECROSS, -32 0167'S 115 8333'E, NORRIS, K. R., 28-06-35, C31100, WALPOLE INLET CAMP SITE, -34 9833'S 116 7333'E, NICHOLLS COLLECTION, 12-01-33, C31101, APPLECROSS, -32 0167'S 115 8333'E, NORRIS, K. R., 28-06-35, C31102, PEMBERTON HL62 BIG BROOK 12, -34 2667'S 115 9333'E, SPRINGETT, J. A., 15-11-71, C31103/4, PEMBERTON HV64 MARRI RD, -34 5000'S 116 0833'E SPRINGETT, J. A., 03-12-71, C31105, PEMBERTON HU61, -34 5000'S, 116 0000'E, SPRINGETT, J. A., 09-11-71, C31106, PORONGURUPS DAM, -34 6667'S 117 8333'E, SPRINGETT, J. A., 22-05-70, L41, C31107, MANJIMUP, -34 2500'S 116 2500'E, SPRINGETT, J. A., 13-04-71, C31108, MANJIMUP GY55 GRAY PINE CREEK RD, -34 2500'S 116 0000'E, SPRINGETT, J. A., 08-11-71, L10, C31109 TWO PEOPLES BAY TICK FLAT WEATHER STATION, -34 9833'S 118 1667'E, BURBIDGE, A. A. & SPRINGETT, J. A., 16-10-70, C31110 SHANNON HP81 MARCH RD SUTTON BLOCK, -34 6000'S 116 4000'E, SPRINGETT, J. A., 16-11-71, C31111, PEMBERTON HQ58 WARREN NATIONAL PARK, -34 4167'S 115 9167'E, SPRINGETT, J. A., 19-05-70, C31112, PEMBERTON-VASSE, -34 4500'S 116 0333'E, SPRINGETT, J. A., 23-09-71 B10, C31113, PORONGURUPS, -34 6667'S 117 8333'E, SPRINGETT, J. A., 09-04-71, B10 C31114, TWO PEOPLES BAY TICK FLAT NSB PAST HUT, -34 9833'S 118 1667'E SPRINGETT, J. A., 22-05-70 C31115, TORNDIRRUP NATIONAL PARK 9 KM S OF ALBANY, -

35 0900°S 117 8333°E, DYER, P H & LYON, J L , 09-11-83, P1, C31116, NINDUP W OF WITCHCLIFFE, -34 0500°S 115 0500°E, WALDOCK, J M , 06-02-93, L41, C31117, WEST CAPE HOWE NATIONAL PARK, S OF TORBAY HILL NR SOUTH ROAD, -35 0833°S 117 6333°E, HARVEY, M S & WALDOCK, J M , 27-03-93, B10, C31118, GNOOCARDUP, -33 9333°S 115 0000°E, SLACK-SMITH, S , 04-08-85, C31119, SHANNON NATIONAL PARK DOG POOL ON SHANNON RIVER 3 KM N, -34 7500°S 116 3667°E, HARVEY, M S & WALDOCK, J M , 30-04-90, R2, C31120, PORONGURUP NATIONAL PARK S END OF MILLINUP PASS, -34 7000°S 117 9000°E, HARVEY, M S & WALDOCK, J M , 31-03-93, L10, C31121, WALPOLE INLET CAMP SETTLEMENT, -34 9833°S 116 7333°E, NICHOLLS COLLECTION, 30-12-32, C31122, APPLECROSS, -32 0167°S 115 8333°E, NORRIS, K R , 10-06-35, C31123/4, WALPOLE CAMP SITE, -34 9833°S 116 7167°E, NICHOLLS COLLECTION, 04-01-33, C31125, FRANKLAND RIVER, -35 0000°S 116 8167°E, NICHOLLS COLLECTION, 04-01-33, C31126 DENMARK, -34 9667°S 117 3500°E, WAMMERSLEY, MR ??-??-??, C31127, WALPOLE, -34 9833°S 116 7167°E, NICHOLLS COLLECTION, ??-01-33, C31128, SWARBRICK'S TRACK VIA ALBANY, -35 0000°S 116 8167°E, NICHOLLS COLLECTION, 03-01-33, C31129, ARMADALE, OLD ALBANY ROAD, -32 1500°S 116 0000°E, COLLECTOR UNKNOWN, 18-06-62, C31130, DENMARK, -34 9500°S 117 3500°E, MCMILLAN, R P , 04-05-95, G20, C31131, GLENBOURNE FARM OLD ELLENSBROOK ROAD NEAR MARGARET RIVER, -33 9167°S 115 0167°E, MARSH, L ET AL , 28-10-96, P2, C31132, GLENBOURNE FARM OLD ELLENSBROOK ROAD NEAR MARGARET RIVER, -33 9167°S 115 0167°E, MARSH, L ET AL , 15-09-97, P2, C31133, WALPOLE INLET CAMP SITE, -34 9833°S 116 7167°E, NICHOLLS COLLECTION, 30-12-32, B10, C31134/38, WALPOLE NORNALUP NATIONAL PARK, -34 9833°S 116 7167°E, WALLIS, N , ??-??-91, C31139/40, STIRLING RANGE NATIONAL PARK MT MAGOG, -34 3997°S 117 9431°E, WALDOCK, J M & MAIN, B Y , 03-09-96, P3, C31141, STIRLING RANGE NATIONAL PARK WHITE GUM FLAT, -34 4000°S 117 9167°E, WALDOCK, J M & SAMPEY, A , 11-06-93, L10, C31142, STIRLING RANGE NATIONAL PARK CARAVAN PARK, -34 3167°S 118 2000°E, HARVEY, M S & WALDOCK, J M , 02-04-93, L42, C31143, STIRLING RANGE NATIONAL PARK TOOLBRUNUP PEAK TRACK, -34 3922°S 118 0589°E, WALDOCK, J M & MAIN, B Y , 03-09-96, P3, C31144, STIRLING RANGE NATIONAL PARK TOOLBRUNUP PEAK TRACK SCREE SLOPE, -34 4000°S 118 0667°E, HARVEY, M S & WALDOCK, J M , 31-03-93, R1, C31145, STIRLING RANGE NATIONAL PARK TOOLBRUNUP PEAK TRACK, -34 4000°S 118 0667°E, WALDOCK, J M. & SAMPEY, A., 10-06-93, L10, C31146, STIRLING RANGE NATIONAL PARK TOOLBRUNUP PEAK TRACK, -34.4000°S 118 0667°E, HARVEY, M S , 02-04-93, L10, C31147, WINDY HARBOUR CLIFFS, EPHEMERAL BURNT PEAT LAKE, -34 8269°S 116 0186°E, HORWITZ, P ET AL , ??-01-94, A20, C31148, CHESAPEAKE ROAD 3 SHRUBLAND ALONG CREEK LINE, -34 8431°S 116 3717°E, HORWITZ, P ET AL , ??-07-94, L80, C31149, INLET RIVER SEDGELAND SWAMP, -34 9175°S 116 5672°E, HORWITZ, P ET AL , ??-01-94, L80, C31150, GLENBOURNE FARM OLD ELLENSBROOK ROAD NEAR MARGARET RIVER, -33 9167°S 115 0167°E, MARSH, L ET AL , 11-07-98, P2, C31151, KARRAGULLEN, -32 1167°S 116 1500°E, GRAHAM, R , 23-10-99, B40, C31152/3, WALPOLE NORNALUP NATIONAL PARK TINGLE CREEK FOREST, -34 9750°S 116 7917°E, VAN HEURCK, P ET AL , 14-05-97, G30, C31154, GLENBOURNE FARM OLD ELLENSBROOK ROAD NEAR MARGARET RIVER, -33 9167°S 115 0167°E, MARSH, L ET AL , 26-10-98, P2, C31155, GLENBOURNE FARM OLD ELLENSBROOK ROAD NEAR MARGARET RIVER, -33 9167°S 115 0167°E, MARSH, L ET AL , 01-11-99, P2, C31837, JANDAKOT AIRPORT, -32 0919°S 115 8744°E, WALDOCK, J M & LONGBOTTOM, A F , 04-11-94, P3, C31838, JANDAKOT AIRPORT, -32 0933°S 115 8775°E, WALDOCK, J M & LONGBOTTOM, A F , 01-09-94, P3

Diagnosis: Habitus clinger/creeper. Animal not white. Body outline interrupted at junction of pereon and pleon. Head with moderately or well developed lateral lobes. Dorsal surface with well-defined tubercles, or bumpy but without bumps arranged in longitudinal rows. Pereonites without conspicuous setae. Animal flatter with pereonal epimera moderately or well extended laterally.

Remarks: This taxon represents a complex of species. Their determination is complicated by the fact that they often occur together in wetter parts of the region and because the juveniles of the form illustrated in Plate 3.57b look similar to the adults of the form shown in Plate 3.57a. The task of describing these species fully is difficult because males are often absent and because species are sometimes extremely small and dissection of all appendages is required. However, the task is made easier because it has already been done for Tasmanian Styloniscidae by Green (1971) who established reliable specific characters and provided a key to the species.

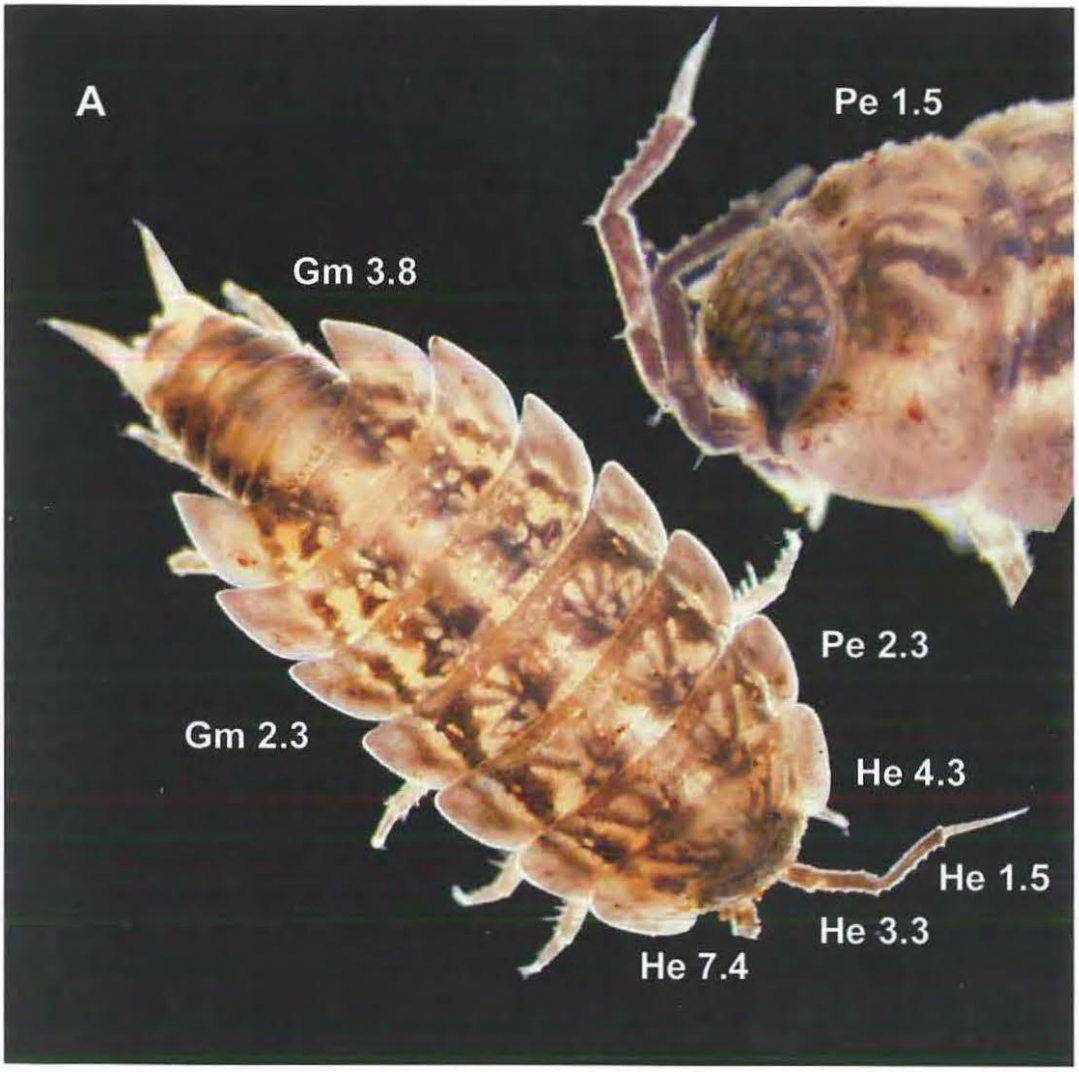


Plate 3.57a. Styloniscus species 7 from the Porongurup Range National Park (C30027) (length 5 mm).

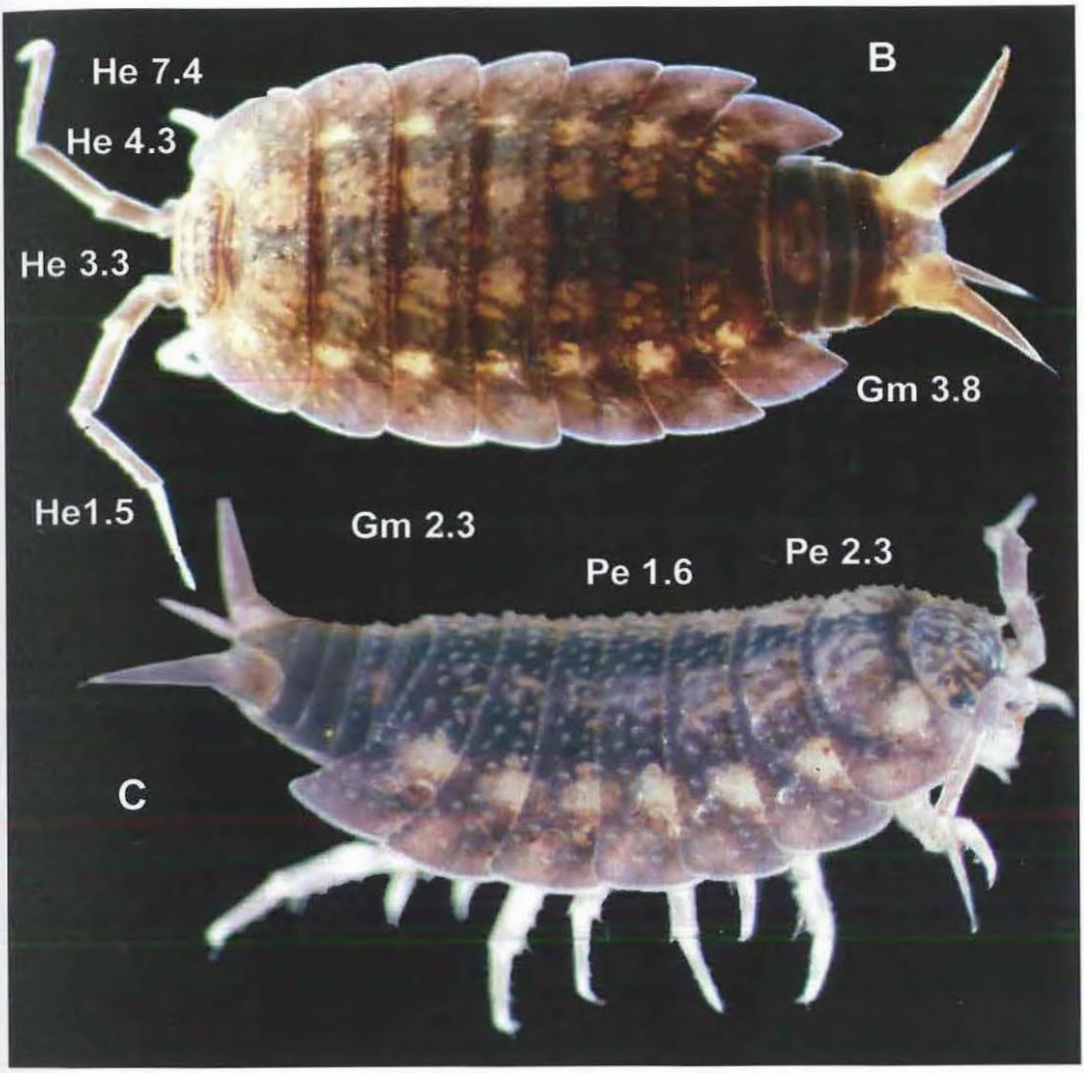


Plate 3.57b. Styloniscus species 7 from (B) Big Brook Forest, near Pemberton (C30004) (length 6 mm) and (C) Mount Frankland National Park (C30035) (length 4.5 mm).

3.14. FAMILIES PLATYARTHRIDAE VERHOEFF AND BATHYTROPIDAE VANDEL

Diagnosis: Non-conglobating. Body length usually small, generally less than 5 mm in Platyarthridae and very dorso-ventrally flattened. Body size larger in Bathytropidae. Animal usually white or very pale in colour in Platyarthridae. Flagellum of second antenna with 2 articles. Eye small, fewer than 10 ommatidia, degenerate or absent in Platyarthridae. Pereon with conspicuous scales. Pleonal epimera 3-5 large or moderate size, therefore body outline not or scarcely interrupted between pleon and pereon. Without pleopodal lungs in exopodites of pleopods. Telson triangular.

Remarks: Both Platyarthridae and Bathytropidae are characterized mainly by possessing a two-jointed flagellum of the second antenna and lacking pleopodal lungs. Taiti, Ferrara and Kwon (1992) suggested that the two families are synonymous. Lewis (1998b) suggested that the two, although sharing the same principal characters, were distinct and unmistakable in their gross morphology. However, she failed to say what these distinctions were. Since there is great similarity in the two families they are treated here in the same section.

MATERIAL EXAMINED BUT DETERMINED ONLY TO FAMILY: C31006, TORNDIRRUP NATIONAL PARK SHARP POINT, -35.1100°S 117.8667°E, HARVEY, M. S & WALDOCK, J M., 26-03-93, R4.

3.14.1. PLATYARTHRIDAE

3.14.1.1. Platyarthridae species 1

Plate 3.2, Gm 2.5; Plate 3.5, He1.3; Plate 3.6, He 2.1; Plate 4.6 He 4.6; Plate 3.11, He 7.6; Plate 3.34, Pl 1.2; Plate 3.40, Pl 7.2; Plate 3.58.

Trichorhina australiensis Wahrberg,1922

Trichorhina australiensis Vandel, 1973

Trichorhina australiensis Bunn and Green, 1982

Platyarthridae/Trachelipidae sp. nov. Bunn and Green, 1982

Diagnosis: Habitus creeper. Animal small (<5 mm) flat and pale cream or white. Eyes of less than 6 ommatidia. Head with well developed subtriangular lateral lobes. Pleonal epimera thinner and tapering to sharp point.

MATERIAL EXAMINED: C2075/80, ROTTNEST ISLAND URSULA'S LAKE, -32.0000°S 115 5000°E, GLAUERT, L., ??-09-27, C3134, CLAREMONT, -31.9833°S 115.7833°E, ALEXANDER, W. B , 10-05-12, S1, C12899, ROTTNEST ISLAND ISLET 30, -32.0000°S 115 5000°E, BUNN, S., 07-05-80, R1; C12900, ROTTNEST ISLAND ISLET 37, -32.0000°S 115 5000°E, BUNN, S., 07-05-80, C12901, ROTTNEST ISLAND ISLET 38, -32.0000°S 115.5000°E, BUNN, S , 07-05-80, C12902, ROTTNEST ISLAND ISLET 13, -32 0000°S 115 5000°E, BUNN, S , 08-05-80; C12903, ROTTNEST ISLAND ISLET 37, -32 0000°S 115.5000°E, BUNN, S , 07-05-80, C29719, MOUNT DALE, -32 0885°S 116 2810°E, JUDD, S & WATSON, A , 21-06-01, G10; C29739, NILGEN NATURE RESERVE TUKEY TRACK, -30 8730°S 115 3070°E, JUDD, S , 07-08-98, L10; C29740, BINDOON SPRING, -31 4080°S 116.3670°E, JUDD, S , 09-10-98, L42, C29741, BINDOON SPRING, -31 4080°S 116 3670°E, JUDD, S., 09-10-98, G40, C29742, NAMBUNG NATIONAL PARK, -30 5420°S 115 1430°E, JUDD, S , 15-10-98, G40; C29743, NAMBUNG NATIONAL PARK LAKE THETIS, -30 5070°S 115 0820°E, JUDD, S., 16-10-98, S1; C29744, MOUNT BYROOMANNING NR, -31 3730°S 116 1270°E, JUDD, S., 18-10-98, G30; C29745, CLACKLINE NATURE RESERVE, -31.7000°S 116 4830°E, JUDD, S , 20-10-98, G30; C29746, LUPTON CONSERVATION PARK NORTH, -32.4470°S 116 6430°E, JUDD, S , 26-10-98, L10; C29747/8, MOORAPULLING NATURE RESERVE, -32 9020°S 116 5730°E, JUDD, S., 28-10-98,

G30; C29749, NARLINGUP NATURE RESERVE, -33 8630°S 116 8900°E, JUDD, S , 29-10-98, G30, C29750, BOOLADING NATURE RESERVE, -33 3500°S 116 6270°E, JUDD, S , 30-10-98, G30, C29751, BOMBAKUP STATE FOREST, -34 6080°S 116 0320°E, JUDD, S , 28-01-99, B10, C29752, MOUNT DALE, -32 1259°S 116 2951°E, WATSON, A , 01-10-01, P3, C29753, MOUNT DALE, -32 0899°S 116 2961°E, WATSON, A , 01-10-01, P3, C29754, MOUNT DALE, -32 1028°S 116.2861°E, JUDD, S & WATSON, A., 26-06-01, G10, C29755, MOUNT DALE, -32 0918°S 116 2779°E, WATSON, A , 01-10-01, P3, C29756, MOUNT DALE, -32 0834°S 116 2831°E, JUDD, S & WATSON, A , 14-12-01, G10, C29757, MOUNT DALE, -32 0869°S 116.2928°E, JUDD, S & WATSON, A , ??-06-01, G10, C29758/9, MOUNT DALE, -32 1040°S 116 2766°E, WATSON, A., 01-10-01, P3, C30992, TORNDIRRUP NATIONAL PARK 9 KM S OF ALBANY, -35 0167°S 117 8333°E, DYER, P H & LYON, J L , 09-11-83, P1, C30993, GARDNER RIVER 2 7 KM W, -34 8000°S 116 1667°E, HARVEY, M S & WALDOCK, J M , 01-05-90, C30994, YANCHEP NATIONAL PARK BOOMERANG GORGE, -31 5333°S 115 6167°E, WALDOCK, J M & SAMPEY, A , 20-04-93, L10, C30995, WEST CAPE HOWE NATIONAL PARK, S OF TORBAY HILL NR SOUTH ROAD, -35 0833°S 117 6333°E, HARVEY, M S & WALDOCK, J M , 27-03-93, B10; C30996, WALPOLE CAMP SITE, -34 9833°S 116 7167°E, NICHOLLS COLLECTION, 12-01-33; C30997, DEEP RIVER RUNS INTO NORNALUP INLET, -35 0000°S 116 6667°E, NICHOLLS COLLECTION, 31-12-32, C30998, POINT PERON, -32 3000°S 115 7000°E, COLLECTOR UNKNOWN, 30-05-33, C30999, WOOROLOO, -31 8000°S 116 3000°E, NICHOLLS COLLECTION, 01-06-33, C31000, NORNALUP SWARBRICK'S TRACK, -35 0000°S 116 8167°E, NICHOLLS COLLECTION, 08-01-33, C31001, TOODYAY GRANITE GROVE, SALT VALLEY ROAD, 25 KM SW TOODYAY, -31 6667°S 116 4000°E, WALDOCK, J. M , 14-07-96, R2, C31002, 4 75 KM ESE OF MARGARET RIVER, -33 9644°S 115 1228°E, PETERSON, M , 14-02-92, C31003, APPLECROSS/FREMANTLE, -32 0167°S 115 8333°E, NORRIS, K R , 16-06-34; C31004, STIRLING RANGE NATIONAL PARK TALYUBERLUP PICNIC SITE, -34 4156°S 117 9550°E, WALDOCK, J. M & MAIN, B Y , 03-09-96, P3; C31817, WOODMAN POINT, -32.1297°S 115 7564°E, HARVEY, M S & WALDOCK, J M , 19-01-95, P3, C31818, TRIGG DUNE BUSH, -31.8750°S 115 7597°E, HARVEY, M S & WALDOCK, J. M , 28-11-95, P3, C31819, BOLD PARK, -31 9372°S 115 7711°E, HARVEY, M S & WALDOCK, J M , 20-07-93, P3, C31820, BOLD PARK, -31 9372°S 115 7711°E, WALDOCK, J M ET AL , 19-11-93, P3, C31821, BOLD PARK, -31 9372°S 115.7711°E, WALDOCK, J M , 06-01-94, P3, C31822, HEPBURN HEIGHTS, -31 8183°S 115 7672°E, WALDOCK, J M & HARVEY, M S , 28-11-95, P3, C31823, MT CLAREMONT, -31 9608°S 115 7656°E, WALDOCK, J M & LONGBOTTOM, A F , 01-09-94, P3

Remarks: This taxon represents a complex of species. Individuals are extremely small and require examination of both mouthparts for confident generic diagnosis and examination of male pleopods for determination of species. Since it has not yet possible to carry this out, this single taxon accommodates all the Platyarthridae, (including Trichorhina australiensis) except for the Platyarthridae species 2 which differs in some important gross characters.

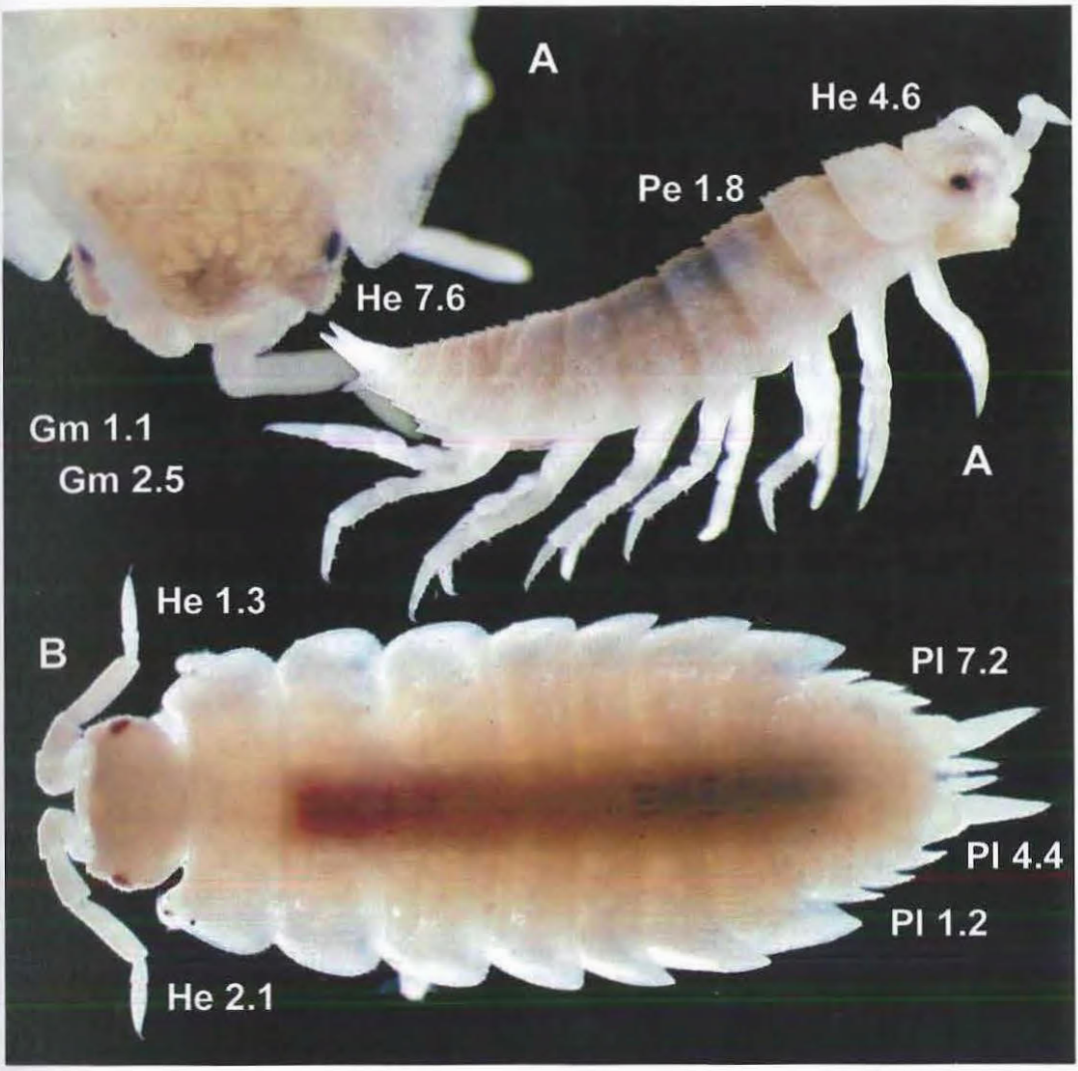


Plate 3.58. Platyarthridae species 1 from (A) Moorapulling Nature Reserve (C29747) (length 2.5 mm) and (B) Rottnest Island (C 12903) (length 3.5 mm).

3.14.1.2. Platyarthridae species 2

Plate 3.11, He 7.5; Plate 3.34, Pl 1.1; Plate 3.59

MATERIAL EXAMINED: C31005, WOOROLOO, -31.8000°S 116.3000°E, COLLECTOR UNKNOWN, 21-04-32.

Diagnosis: Habitus clinger. Animal pale cream or white with eyes of less than 6 ocelli. Head with large rounded lateral lobes. Pleonal epimera broader and tapering to a moderately sharp point.

Remarks: This taxon is represented by a single collection of five specimens. There is no preliminary evidence of pleopodal lungs but further examination is necessary to confirm this. The specimens are seventy years old and the lack of colour may a result of prolonged storage. However, the specimens have very small eyes and definite scales on the dorsal surface and are therefore included in the Platyarthridae. They differ markedly from Platyarthridae species 1 and are unlike anything else from the region. It is possible that they are an introduced species and are probably specimens collected by Bowley.

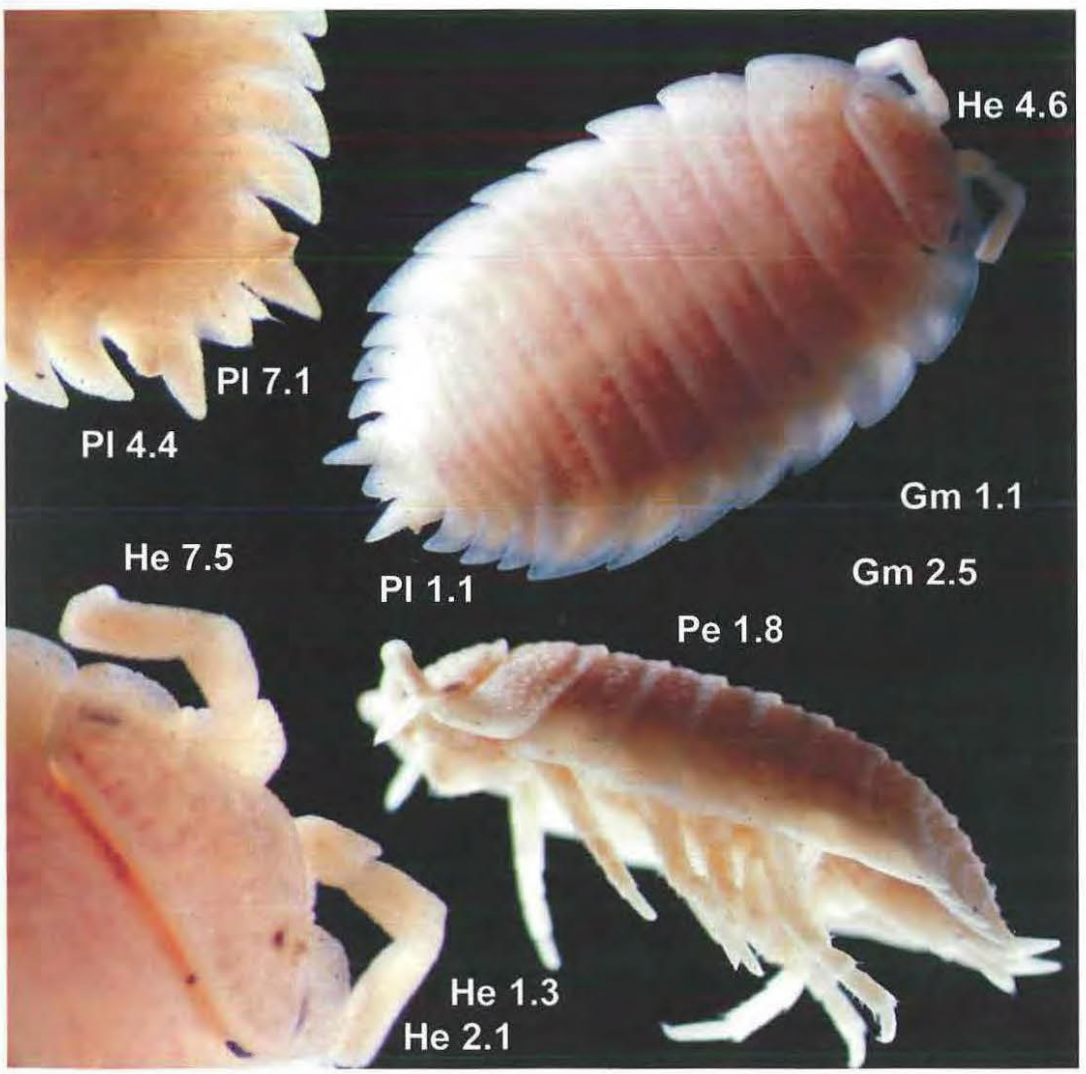


Plate 3.59. Platyarthridae species 2 from Wooroloo (C31005) (length 4 mm).

3.14.1.3. Platyarthridae species 3

Plate 3.4, Gm 4.4; Plate 3.2, Gm 2.1; Plate 3.8, He 4.4; Plate 3.17, Pe 1 8, Plate 3.60.

Australoniscus sp. nov. Judd & Horwitz, 2003

MATERIAL EXAMINED. C29765, WARREN NATIONAL PARK TREAN BROOK, -34 4820°S 115 9250°E, JUDD, S , 13-08-98, B10; C29766, D'ENTRECASTEAUX NATIONAL PARK, QUINERUP SPRING, -34 4420°S 115 6850°E, JUDD, S., 14-08-98, G40; C29767, YANCHEP NATIONAL PARK, -31 5200°S 115 6630°E, JUDD, S , 13-10-98, G40, C29768, LESCHENAULT CONSERVATION PARK, -33 2250°S 115 6920°E, JUDD, S , 25-11-98, L10; C29769, LESCHENAULT CONSERVATION PARK, -33 2250°S 115 6920°E, JUDD, S., 25-11-98, G30, C29770, BENGER SWAMP NATURE RESERVE, -33 1780°S 115 8330°E, JUDD, S , 25-11-98, L10, C29771, BENGER SWAMP NATURE RESERVE, -33 1780°S 115 8330°E, JUDD, S , 25-11-98, B40; C29772, MARGARET RIVER CREEK, -33 9350°S 115 0650°E, JUDD, S , 10-12-98, B10, C29773, MARGARET RIVER CREEK, -33 9350°S 115 0650°E, JUDD, S., 10-12-98, B40; C29774, WAYCHINICUP NATIONAL PARK, -34 8800°S 118 3270°E, JUDD, S , 19-12-98, B10, C29775, TWO PEOPLES BAY NATURE RESERVE, -34 9770°S 118 1820°E, JUDD, S , 19-12-98, G40, C29776, RATE BLOCK, -34 8350°S 117.0070°E, JUDD, S , 09-01-99, B10, C29777, RATE BLOCK, -34 8350°S 117 0070°E, JUDD, S., 09-01-99, L41, C29778/9, SHANNON NATIONAL PARK (FISH CREEK ROAD), -34 6250°S 116 4370°E, JUDD, S., 27-01-99, B10, C29780, SHANNON RIVER/CHESAPEAKE RD , -34 8420°S 116 3700°E, JUDD, S , 27-01-99, B10, C29781, BOMBAKUP STATE FOREST, -34 6080°S 116 0320°E, JUDD, S., 28-01-99, B10, C29782, MT CHUDALUP, -34 7630°S 116 0830°E, JUDD, S , 28-01-99, L10, C29783, MT CHUDALUP, -34 7630°S 116 0830°E, JUDD, S , 28-01-99, B10, C29784, MT CHUDALUP, -34.7630°S 116 0830°E, JUDD, S , 28-01-99, L10, C29785/6, GINGILUP SWAMPS NATURE RESERVE, -34 3320°S 115 4400°E, JUDD, S , 09-12-98, L20, C31017, TORNDIRRUP NATIONAL PARK 9 KM S. OF ALBANY, -35 0900°S 117 8333°E, DYER, P H. & LYON, J L., 09-11-83, P1, C31018, PEMBERTON 4 KM NW, -34 4167°S 115 9500°E, HARVEY, M S. & WALDOCK, J M , 02-05-90, C31019, SHANNON NATIONAL PARK DOG POOL ON SHANNON RIVER, -34 7667°S 116 3667°E, HARVEY, M S & WALDOCK, J. M., 30-04-90, B10, C31020, WALPOLE ROAD TO WALPOLE NEAR LAND LEACH GULLY, -34 9833°S 116.7167°E, NICHOLLS COLLECTION, 23-11-38, C31021, WALPOLE NORNALUP NATIONAL PARK TINGLE CREEK FOREST, -34 9750°S 116 7833°E, VAN HEURCK, P ET AL., 16-05-97, B40; C31824, WOODMAN POINT, -32.1328°S 115.7581°E, HARVEY, M. S. & WALDOCK, J M., 06-07-95, P3, C31825, WOODMAN POINT, -32 1328°S 115 7581°E, WALDOCK, J M. & LONGBOTTOM, A F , 04-11-94, P3, C31826, WOODMAN POINT, -32 1328°S 115 7581°E, HARVEY, M. S. & WALDOCK, J M., 21-03-95, P3; C31827, WOODMAN POINT, -32 1328°S 115 7581°E, HARVEY, M. S & WALDOCK, J. M., 06-07-95, P3; C31828/9, WOODMAN POINT, -32 1328°S 115 7581°E, WALDOCK, J M & LONGBOTTOM, A F , 01-09-94, P3, C31830, WOODMAN POINT, -32 1306°S 115 7578°E, HARVEY, M S & WALDOCK, J. M., 04-05-95, P3, C31831, WOODMAN POINT, -32 1328°S 115 7581°E, HARVEY, M. S & WALDOCK, J. M., 21-03-95, P3, C31832, WOODMAN POINT, -32 1328°S 115 7581°E, HARVEY, M. S & WALDOCK, J M., 19-01-95, P3.

Diagnosis: Habitus creeper. Animal with brownish colouring and cream patches. Eyes prominent with more than 6 ocelli. Animal small and slightly convex. Head with prominent lateral and medial lobes. Dorsal surface with very prominent fine scale setae. Animal 2 to 3 times long as broad.

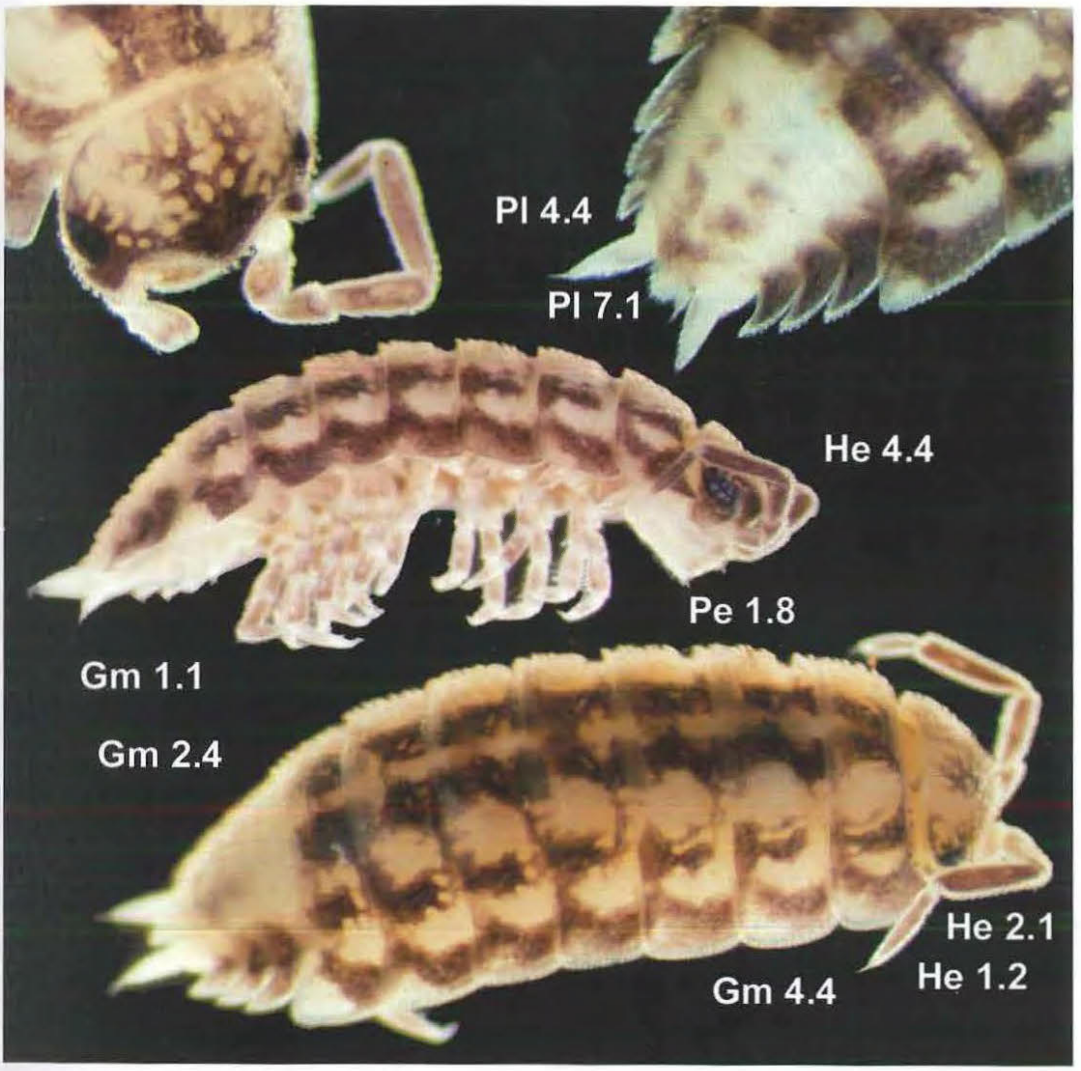


Plate 3.60. Platyarthridae species 3 from Warren National Park (C 29765) (length 3.5 mm).

3.14.1.4. Platyarthridae species 4

Plate 3.4, Gm 4.5; Plate 3.8, He 4.5; Plate 3.61.

Australoniscus sp. nov. Judd & Horwitz, 2003

MATERIAL EXAMINED: C29787, BUNDARRA NATURE RESERVE, -30.9250°S 115.8250°E, JUDD, S., 04-10-98, L10; C29788, BUNDARRA NATURE RESERVE, -30.9250°S 115.8250°E, JUDD, S., 04-10-98, G20; C29789, MOUNT BYROOMANNING NR, -31.3730°S 116.1270°E, JUDD, S., 18-10-98, R1; C29790, WHITE HORSE HILL, -32.6070°S 116.2950°E, JUDD, S., 06-11-98, L10.

Diagnosis: Habitus creeper. Small (<5 mm) and cylindrical. Dorsal surface with fine setae. Animal with light brown or orange-brown colouring. Head with moderately developed lateral lobes and prominent medial lobe. Eyes prominent, with more than 6 ocelli. Animal 4 to 5 times long as broad.

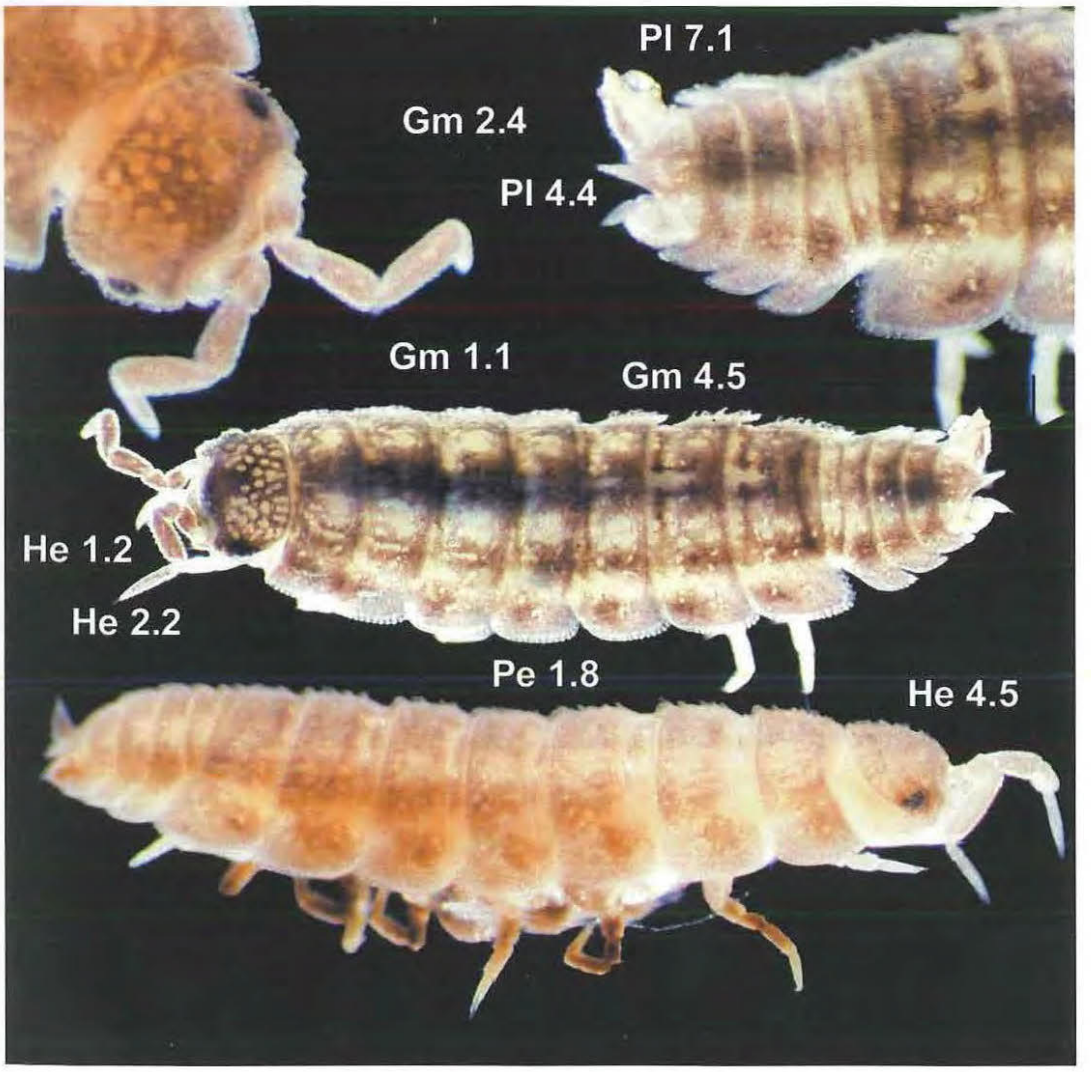


Plate 3.61. Platyarthridae species 4 from Bundarra Nature Reserve (C29787/8) (length 3.5 mm).

3.14.2. GENUS AUSTRALONISCUS VANDEL

Diagnosis: Vandel's (1973a) diagnosis for the genus is brief and includes very general characters. Translated from the original French it reads: "General morphology similar to Porcellio with body outline not interrupted at the junction of pereon and pleon. Anterior of head with three definite and individual lobes. Telson triangular. Flagellum with two articles and pleopod exopodites without lungs".

3.14.2.1. Australoniscus springetti Vandel, 1973

Plate 3.4, Gm 4.3; Plate 3.5, He 1.2; Plate 3.6, He 2.2; Plate 3.17, Pe 1.7; Plate 3.40, Pl 7.1; Plate 3.62.

Australoniscus springetti Vandel, 1973

Australoniscus springetti Judd & Horwitz, 2003

TYPE MATERIAL EXAMINED: C11022, HOLOTYPE, PORONGURUP RANGE, WA, SPRINGETT, J A, 07-04-71.

MATERIAL EXAMINED: C29718, PORONGURUP NATIONAL PARK TREE IN THE ROCK, -34 6833°S 117 8333°E, HARVEY, M. S. & WALDOCK, J. M., 30-03-93, C29760, PORONGORUP NATIONAL PARK BOLGANUP DAM, -34.6700°S 117 8820°E, JUDD, S., 16-12-98, B10; C29761, PORONGORUP NATIONAL PARK BOLGANUP DAM, -34 6700°S 117.8820°E, JUDD, S , 16-12-98, L41; C29762, PORONGORUP NATIONAL PARK BOLGANUP DAM, -34 6700°S 117 8820°E, JUDD, S , 16-12-98, L10; C29763/4, PORONGORUP NATIONAL PARK WANSBROUGH WALK, -34.6830°S 117 8480°E, JUDD, S , 16-12-98, L10; C31007, PORONGURUPS, -34.6667°S 117.8333°E, BOWLEY, E. A , 16-12-28; C31008, PORONGURUPS, -34 6667°S 117 8333°E, BOWLEY, E A, 20-04-35; C31009/10, PORONGURUPS DAM, -34.6667°S 117.8333°E, SPRINGETT, J. A , 22-05-70, L41; C31011, PORONGURUPS KARRI CAR PARK TOP NT PK. DEVILS SLIDE, -34 6667°S 117.8333°E, SPRINGETT, J. A., 09-04-71, L41; C31012, PORONGURUPS, -34 6667°S 117.8333°E, SPRINGETT, J A., 09-04-71, B10; C31013, PORONGURUPS DAM, -34.6667°S 117 8333°E, SPRINGETT, J. A , 22-05-70, L10; C31014, PORONGURUP NATIONAL PARK S END OF MILLINUP PASS, -34.7000°S 117 9000°E, HARVEY, M. S. & WALDOCK, J. M , 30-03-93, B10; C31015, PORONGURUP NATIONAL PARK S END OF MILLINUP PASS, -34.7000°S 117 9000°E, HARVEY, M. S. & WALDOCK, J M., 31-03-93, L10, C31016, PORONGURUP NATIONAL PARK S END OF MILLINUP PASS, -34.6953°S 117.8975°E, HARVEY, M. S., 02-09-96, P3.

Diagnosis: Habitus clinger. Animal of large or moderate size with light or dark brownish colouring overall and prominent pale markings. Eyes prominent with more than 6 ocelli. Animal flat and wide. Dorsal surface without dense setae. Known only from the Porongurup Range.

Remarks: The type locality for this species was given incorrectly by Vandel (1973). See Section 3.2.3 for details.

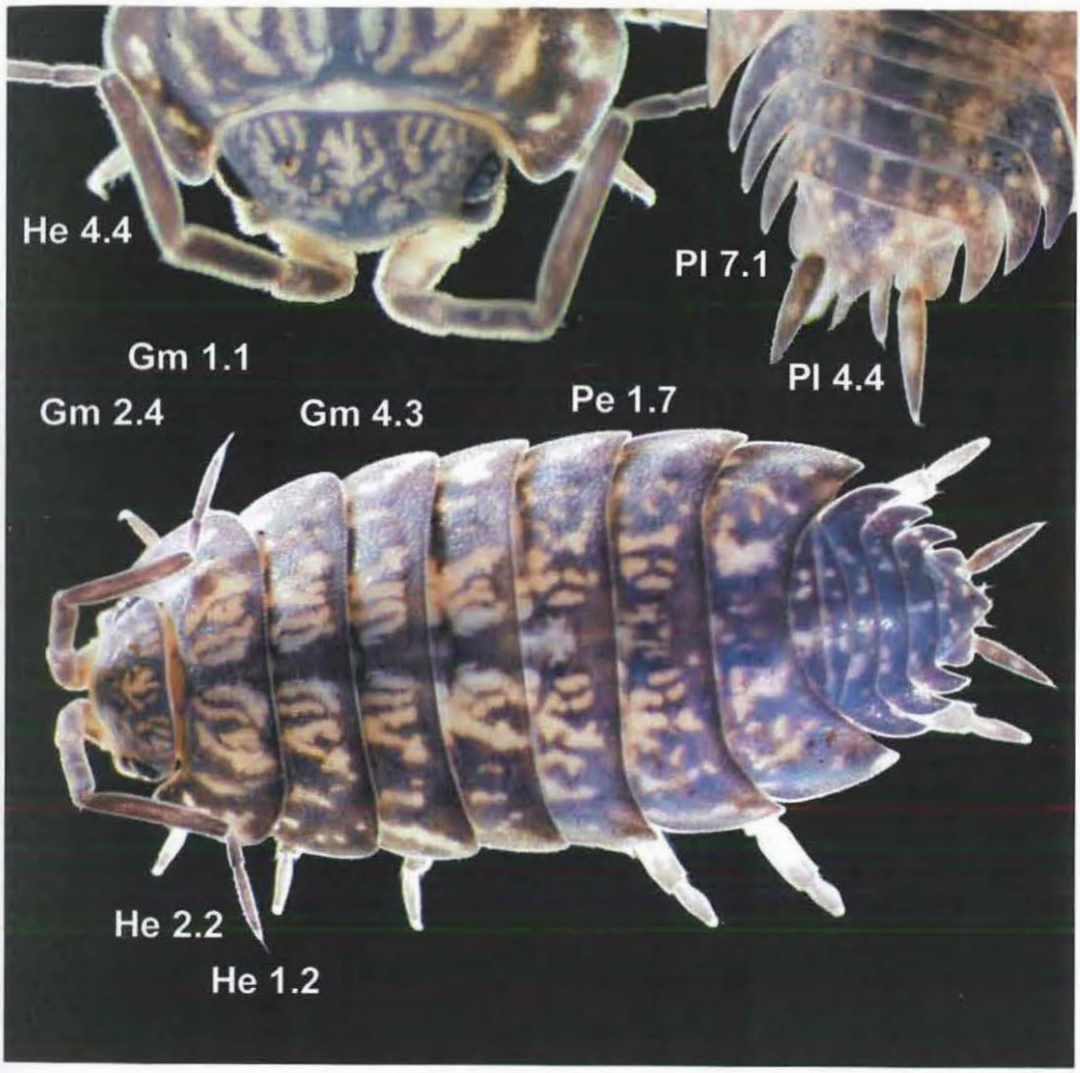


Plate 3.62. **Australoniscus springetti from Porongurup Range National Park (C29762/3) (length 7.5 mm).**

3.15. FAMILY ONISCIDAE LATREILLE

MATERIAL EXAMINED BUT DETERMINED ONLY TO FAMILY C30966, TWO PEOPLES BAY, -34.9833°S 118.1667°E, SPRINGETT, J A , ??-??-??; C30967, WALPOLE ROAD TO WALPOLE NEAR LAND LEACH GULLY, -34 9833°S 116 7333°E, NICHOLLS COLLECTION, 23-11-38; C30968, BOYNDIMINUP ROAD VERY LOW DRY SHRUBLAND, -34.5142°S 116.5856°E, HORWITZ, P. ET AL., ??-10-94, A30

Diagnosis: Non-conglobating. Flagellum of second antenna with 3 articles. Head with lateral lobes and sometimes median lobe along frontal line. Pereon without noduli laterales. Pleonal epimera 3-5 large or moderate size and therefore body outline scarcely or not interrupted between pleon and pereon. Without pleopodal lungs in exopodites of pleopods. Telson triangular.

3.15.1 GENUS HANONISCUS BUDDE-LUND

Remarks: A generic distinction between Hanoniscus and the New Zealand genus Phalloniscus, based on mouthparts, was made by Bowley (1935). Bowley also described the Western Australian material. The species described here are readily identified from her descriptions without examination of the mouthparts which do not vary between species. Therefore, the generic diagnosis is not repeated here.

3.15.1.1. Hanoniscus monodi Bowley, 1935

Plate 3.3, Gm 3.3; Plate 3.10, He 6.3; Plate 3.17, Pe 1.9, Plate 3.63.

Hanoniscus n. sp. Budde-Lund, 1912

Phalloniscus punctatus Wahrberg, 1922

Phalloniscus (Hanoniscus) monodi Bowley, 1935

Hanoniscus monodi Vandel, 1973

Hanoniscus monodi Judd & Horwitz, 2003

MATERIAL EXAMINED: C29722/5, CHITTERING LAKE RESERVE, -31.4180°S 116.0930°E, JUDD, S , 08-08-98, B40; C29728, CHITTERING LAKE RESERVE, -31.4180°S 116.0930°E, JUDD, S., 08-08-98, B30; C29727, JULIMAR CONSERVATION PARK, -31 3950°S 116.2950°E, JUDD, S., 09-10-98, G30; C29728, HILL RIVER NATIONAL PARK, -30 3030°S 115 1830°E, JUDD, S., 14-10-98, B30.

Diagnosis: Habitus clinger. Central frontal part of head relatively flat without well-developed medial lobe. Pereonites with large and well-defined tubercles.

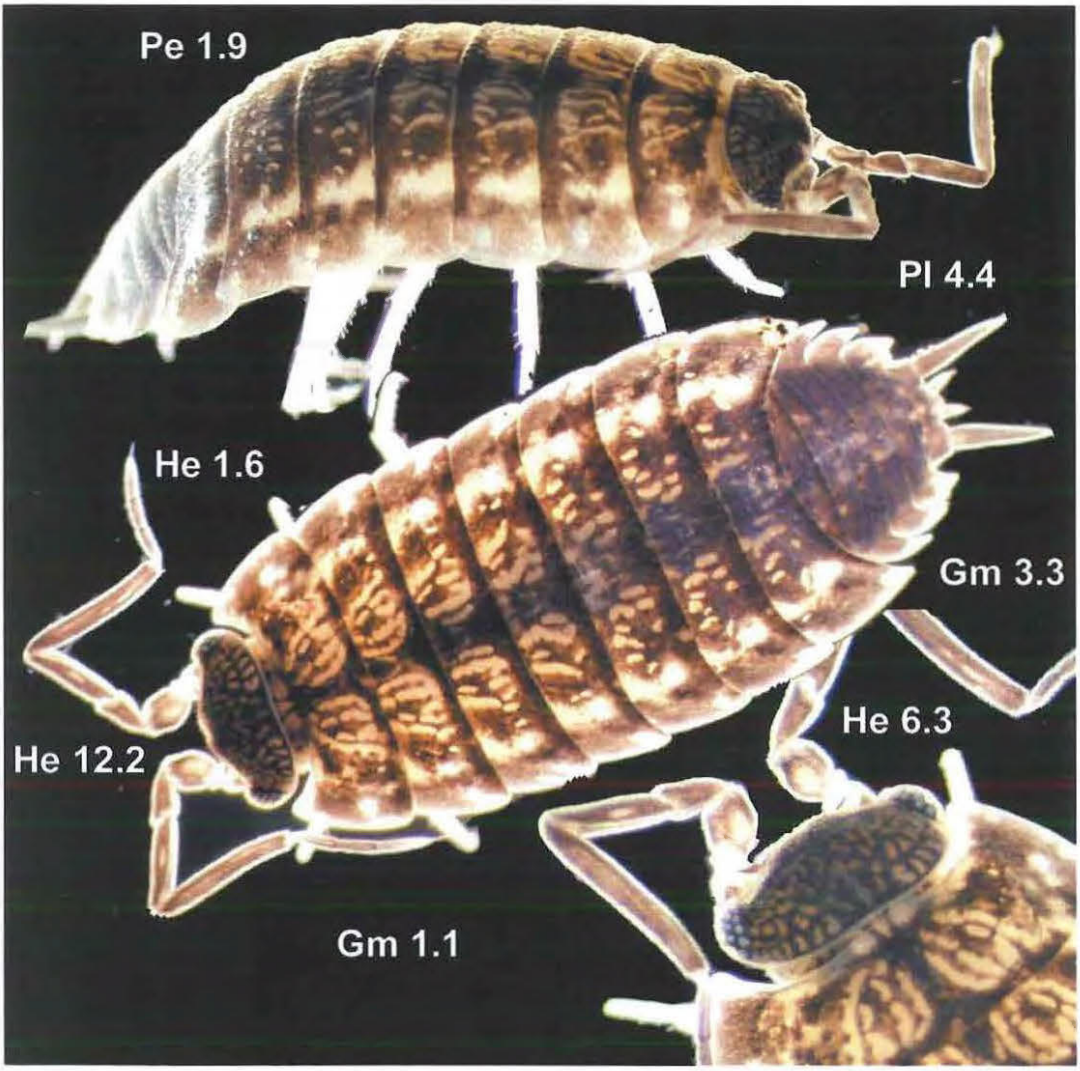


Plate 3.63. Hanoniscus monodi from Chittering Lake Reserve (C 29725) (length 5.5 mm).

3.15.1.2. Hanoniscus nichollsi Bowley, 1935

Plate 3.2, Gm 2.6; Plate 3.5, He 1.6; Plate 3.10, He 6.5; Plate 3.17, Pe 1.10; Plate 3.32, Pe 17.3; Plate 3.64

Hanoniscus n. sp. Budde-Lund, 1912

Phallonisçus (Hanoniscus) nichollsi Bowley, 1935

Hanoniscus nichollsi Vandel, 1973

Hanoniscus nichollsi Judd & Horwitz, 2003

MATERIAL EXAMINED: C29729, WALPOLE NORNALUP NATIONAL PARK TINGLEWOOD, -35.0030°S 116 6380°E, JUDD, S., 07-01-99, L10; C30969/71, NORNALUP INLET, -35.0000°S 116.7167°E, NICHOLLS COLLECTION, ??-??-25, L10; C30972, WALPOLE INLET, -34 9833°S 116 7333°E, NICHOLLS COLLECTION, ??-??-??, L10; C30973/4, WALPOLE INLET CAMP SITE, -34 9833°S 116 7333°E, NICHOLLS COLLECTION, 12-01-33; C30975, WALPOLE NORNALUP NATIONAL PARK JARRAH FOREST, -34 9917°S 116 7083°E, VAN HEURCK, P. ET AL., 13-05-97, G30; C30976, WALPOLE NORNALUP NATIONAL PARK KARRI FOREST, -34 9833°S 116.7083°E, VAN HEURCK, P. ET AL., 13-05-97, B40.

Diagnosis: Habitus clinger. Animal light cream coloured with darker brown patches. Dorsal surface of pereonites irregularly bumpy. Central frontal part of head pointed. Carpus of pereopod 1 of male densely setose.

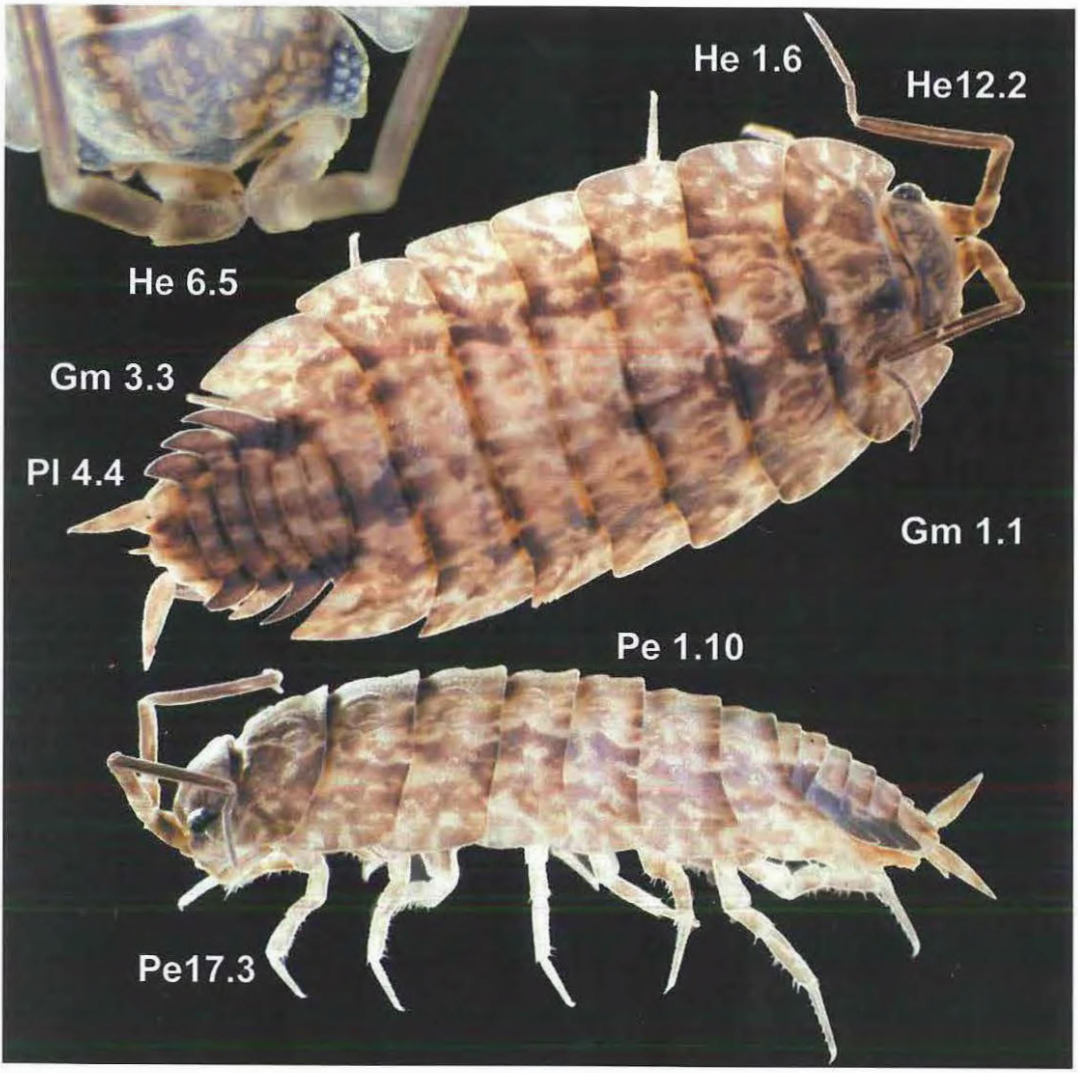


Plate 3.64. <u>Hanoniscus</u> <u>nichollsi</u> **from Walpole Nornalup National Park (C 29729) (length 8 mm).**

3.15.1.3. Hanoniscus tuberculatus Budde-Lund, 1912

Plate 3.10, He 6.4; Plate 3.17, Pe 1.11, Plate 3.33, Pe 17.4; Plate 3.37, Pl 4.4; Plate 3.65.

Hanoniscus tuberculatus. Budde-Lund, 1912

Phalloniscus kenepurensis Wahrberg, 1922

Phalloniscus (Hanoniscus) tuberculatus Bowley, 1935

Hanoniscus tuberculatus Vandel, 1973

Hanoniscus tuberculatus Judd & Horwitz, 2003

MATERIAL EXAMINED: C1337, CANNINGTON, -32.0167°S 115.9500°E, GLAUERT, L., 01-10-23, C1617, FRESHWATER BAY, SWAN RIVER, -32.0000°S 115.7833°E, GLAUERT, L., ??-??-25; C2366, PEPPERMINT GROVE PERTH, -32.0000°S 115.7667°E, GLAUERT, L., ??-??-27; C29730, BENGER SWAMP NATURE RESERVE, -33.1780°S 115.8330°E, JUDD, S., 25-11-98, B40; C30977, TAMBELLUP, -34.0333°S 117.6333°E, BOWLEY, E. A., ??-??-25; C30978/9, CRAWLEY, -31.9833°S 115.8167°E, NICHOLLS COLLECTION, 03-03-33; C30980, CRAWLEY, -31.9833°S 115.8167°E, NICHOLLS COLLECTION, 08-03-33; C30981, CRAWLEY PELICAN POINT, -31.9833°S 115.8167°E, COLLECTOR UNKNOWN, 24-03-33, C30982, CRAWLEY PELICAN POINT, -31.9833°S 115.8167°E, NICHOLLS COLLECTION, 03-03-33, C30983/85, CRAWLEY, -31.9833°S 115.8167°E, NICHOLLS COLLECTION, ??-03-33, C30986, TAMBELLUP, -34.0333°S 117.6333°E, NICHOLLS COLLECTION, 15-09-29, C30987, CRAWLEY, -31.9833°S 115.8167°E, NICHOLLS COLLECTION, 24-02-32, C30988, CRAWLEY PELICAN POINT, -31.9833°S 115.8167°E, NICHOLLS COLLECTION, ??-03-33, C30989, KALAMUNDA, -31.9667°S 116.0667°E, COLLECTOR UNKNOWN, 16-07-33, B40.

Diagnosis: Habitus clinger. Animal dark brown with light coloured patches. Central front part of head rounded. Pereonites with fine tubercles on dorsal surface.

Remarks: Colour has faded in the specimen photographed in Plate 3.65 due to its age.

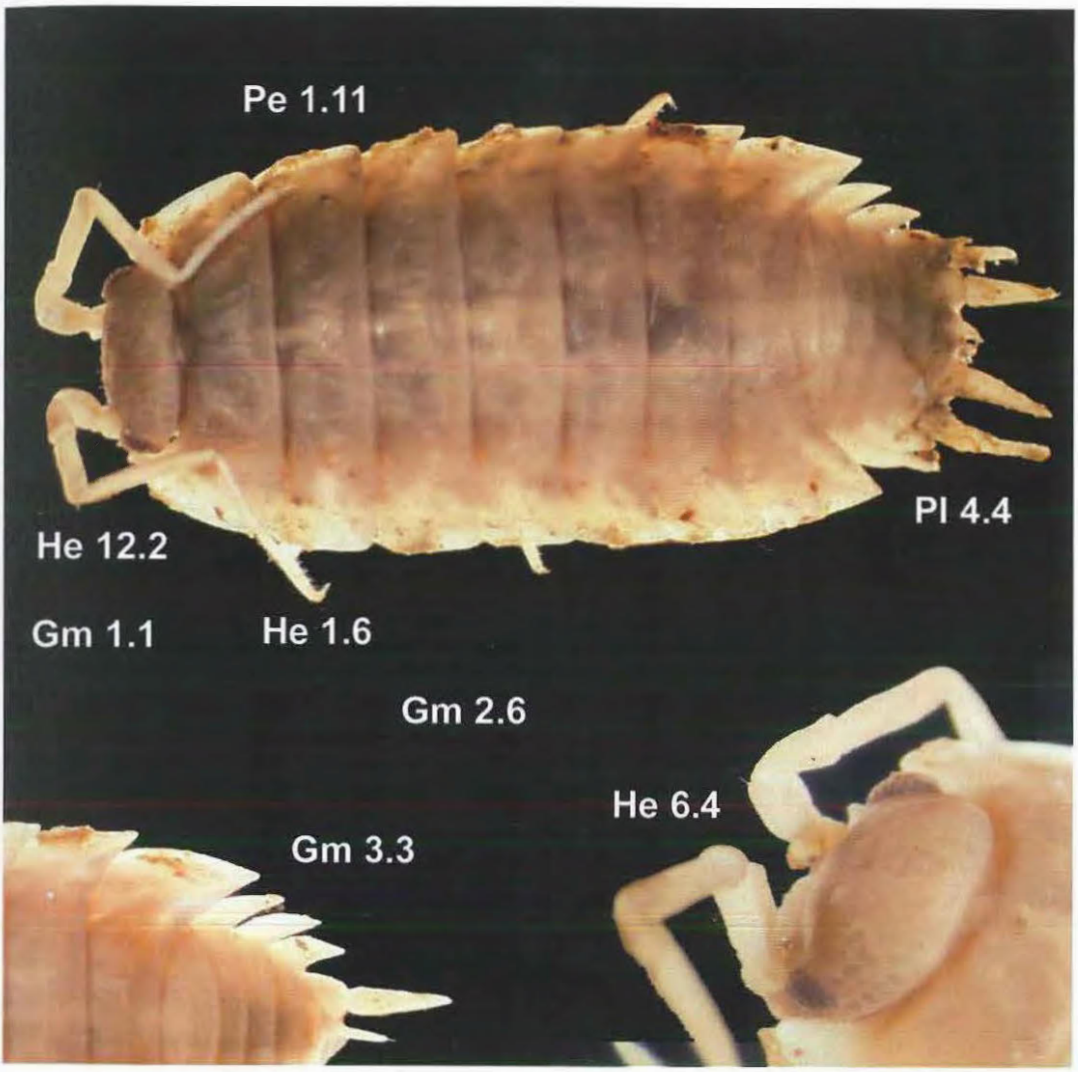


Plate 3.65. Hanoniscus tuberculatus **from Cannington (C1337) (length 8 mm).**

3.15.1.4. Hanoniscus new species

Plate 3.2, Gm 2.7; Plate 3.10, He 6.6; Plate 3.17, Pe 1.12; Plate 3.66.

Hanoniscus sp. nov? Judd & Horwitz, 2003

MATERIAL EXAMINED: C29731, YALGORUP NATIONAL PARK, -32.9130°S 115.6830°E, JUDD, S., 13-11-98, B30; C29732/3, LEEUWIN NATURALISTE NATIONAL PARK HAMELIN BAY, -34.2070°S 115.0380°E, JUDD, S., 10-12-98, L10; C29734/5, LEEUWIN NATURALISTE NATIONAL PARK HAMELIN BAY, -34.2070°S 115.0380°E, JUDD, S., 10-12-98, S1, C29736, LEEUWIN NATURALISTE NATIONAL PARK KARRI NEAR HAMELIN BAY, -34.2000°S 115.0720°E, JUDD, S., 10-12-98, B10, C29737/8, LEEUWIN NATURALISTE NATIONAL PARK KARRI NEAR HAMELIN BAY, -34.2000°S 115.0720°E, JUDD, S., 10-12-98, L10, C30990, GNOOCARDUP, -33.9333°S 115.0000°E, SLACK-SMITH, S., 04-08-85, L50, C30991, GLENBOURNE FARM OLD ELLENSBROOK ROAD NEAR MARGARET RIVER, -33.9167°S 115.0167°E, MARSH, L. ET AL., 31-03-97, P2.

Diagnosis: Habitus clinger. Animal light brown or cream coloured with brown patches. Central front part of head and lateral lobes pointed. Pereonites with fine scales on dorsal surface.

Remarks: This species differs from the other three species in that it is smaller and much longer and thinner. Its colouring and characters of the head resemble H. nichollsi but male specimens lack the dense brush of setae on the carpus of pereopod 1.

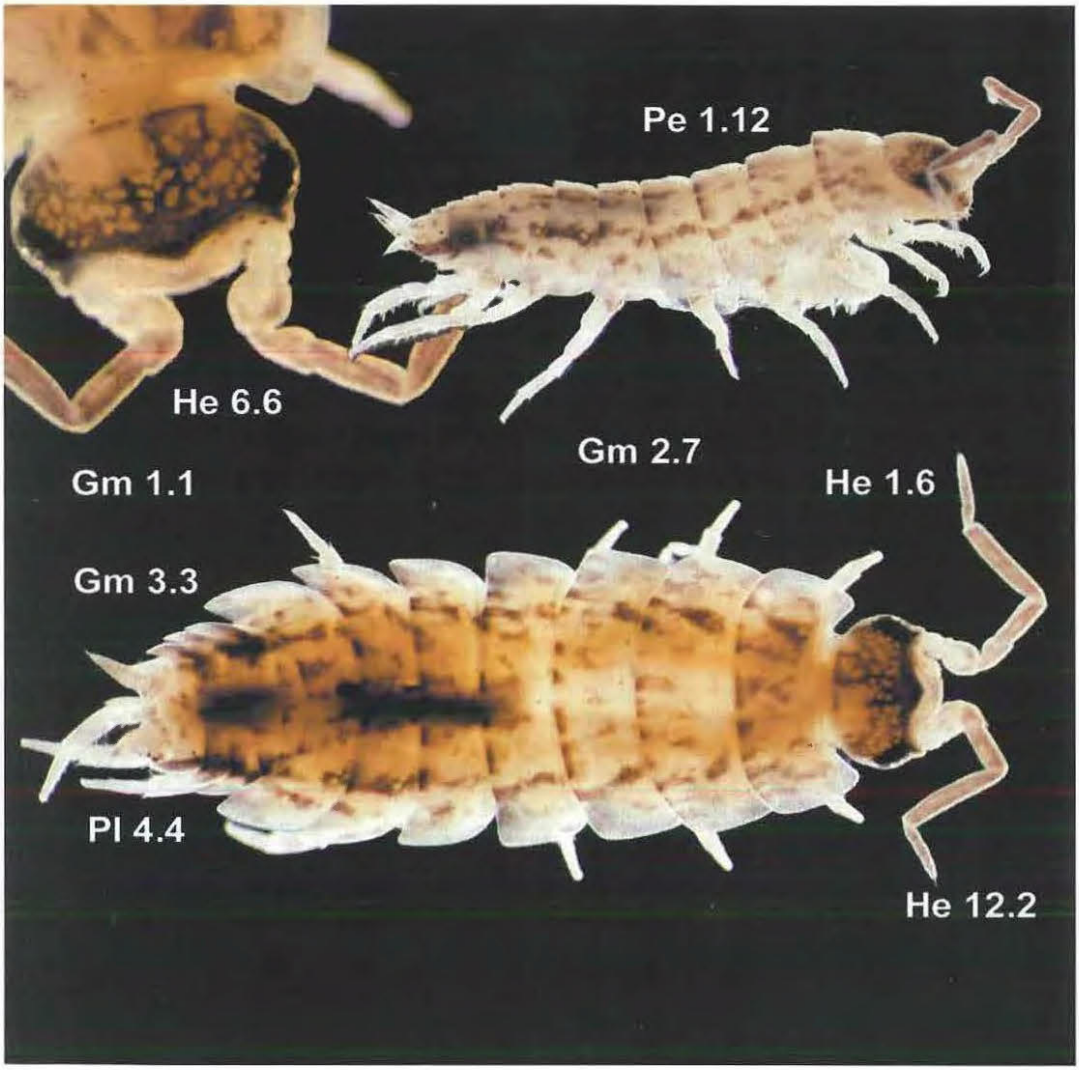


Plate 3.66. Hanoniscus **new species from Hamelin Bay, Leeuwin-Naturaliste National Park (C29732) (length 3.5 mm).**

3.16. FAMILY PHILOSCIIDAE KINAHAN

Diagnosis: Non-conglobating. Flagellum of second antenna with 3 articles. Eyes prominent and composed of many ommatidia. Head without conspicuous lateral or medial lobes. Pereon with noduli laterales. Pleonal epimera 3-5 small, therefore body outline interrupted between pleon and pereon.

MATERIAL EXAMINED BUT DETERMINED ONLY TO FAMILY. C357, CALGARDUP CAVE, -34.0500°S 115 0167°E, COLLECTOR UNKNOWN, 30-12-12, C941, FRESHWATER BAY OSBORNE STEPS, -32.0000°S 115 7833°E, GLAUERT, L., ??-??-23, R1; C1115, BIBRA LAKE, -32 1000°S 115.8167°E, GLAUERT, L., 16-06-23, R1, C1132, CRAIGIE LAKE WANNEROO, -31.7550°S 115 8000°E, GLAUERT, L., 14-07-23, L10; C1336, CANNINGTON, -32 0167°S 115 9500°E, GLAUERT, L., ??-10-23, C1397, FRESHWATER BAY, SWAN RIVER, -32.0000°S 115 7833°E, GLAUERT, L., ??-??-23; C1592/5, KELMSCOTT, -32 1333°S 116 0000°E, GLAUERT, L., 29-09-24; C1618, FRESHWATER BAY, SWAN RIVER, -32.0000°S 115.7833°E, GLAUERT, L., ??-??-25; C2367, PEPPERMINT GROVE PERTH, -32 0000°S 115.7667°E, GLAUERT, L., ??-??-27; C2593, SERPENTINE, -32 3667°S 115.9667°E, GLAUERT, L., ??-??-28; C5192, MANJIMUP, PERUP?, -34 3333°S 116.4500°E, GLAUERT, L., ??-03-36, G30, C11016, MANJIMUP GY55 GRAY PINE CREEK RD, -34.2500°S 116 0000°E, SPRINGETT, J A., 08-11-71; C11020, GLENEAGLE BV72 HAVEL'S PLOT 64, -32.2500°S 116.1667°E, SPRINGETT, J A , 22-10-71; C14484, PERTH, -31.9500°S 115.8500°E, DEP. AGRIC., 03-05-85; C16771, DWELLINGUP 12 MILES S, -32.8833°S 116.0667°E, MUELLER, O , 18-05-86, C18436, TWO PEOPLES BAY, -34.9833°S 118.1667°E, SMITH, G. T , 23-02-77, C21079, MT COOKE, -32.4167°S 116 3000°E, WALDOCK, J. M. & CAR, C. A., 19-10-91, P3; C21080, MT COOKE, -32.4167°S 116.3000°E, WALDOCK, J. M. & CAR, C. A , 28-11-91, P3; C21081, AUGUSTA 1.5 KM NE, -34.3170°S 115 1500°E, HAROLD, G. A., 02-12-85; C21083, AUGUSTA 1 5 KM NE, -34.3036°S 115.1500°E, HAROLD, G. A , 02-12-85; C21084, YORK, -31.8833°S 116 7667°E, BANNISTER, J , 16-11-91, L10; C21091, 8 5 KM SW OF KARRIDALE, -34.2583°S 115 0375°E, HAROLD, G. A , 08-11-85; C29705, STRONG'S CAVE, -34.1500°S 115 0333°E, HOWLETT, R , 29-01-61, S1; C30053, WALYUNGA NATIONAL PARK, -31.7320°S 116.0730°E, JUDD, S., 21-08-98, R2; C30054, WEDGE ISLAND DUNE, -30.8410°S 115 2320°E, JUDD, S , 07-08-98, L10; C30055, NILGEN NATURE RESERVE TUKEY TRACK, -30 8730°S 115.3070°E, JUDD, S., 07-08-98, L10; C30056, WANDOO CONSERVATION PARK, -32 0520°S 116.5450°E, JUDD, S , 22-10-98, L10; C30057, OCCIDENTAL FOREST BLOCK DALE ROAD, -32.1050°S 116.2570°E, JUDD, S., 04-11-98, L10, C30058, OCCIDENTAL FOREST BLOCK DALE ROAD, -32.1050°S 116 2570°E, JUDD, S., 04-11-98, G30; C30059, MONADNOCKS CONSERVATION PARK MARGINATA ROAD, -32 2420°S 116.2050°E, JUDD, S., 04-11-98, L10; C30060, NOGGERUP CONSERVATION PARK, -33 6220°S 116.1230°E, JUDD, S., 24-11-98, G40, C30061, NOGGERUP CONSERVATION PARK, -33 6220°S 116.1230°E, JUDD, S , 24-11-98, L20, C30062, BRIDGETOWN JARRAH PARK, -34 0300°S 115.9830°E, JUDD, S , 01-12-98, G20, C30063/4, ST JOHNS CONSERVATION PARK, -33.9450°S 115.6900°E, JUDD, S , 02-12-98, L10, C30065/6, SCOTT RIVER NATIONAL PARK, -34 3030°S 115 1730°E, JUDD, S., 09-12-98, L10; C30067/8, GINGILUP SWAMPS NATURE RESERVE, -34 3320°S 115.4400°E, JUDD, S., 09-12-98, G40; C30069, WALPOLE NORNALUP NATIONAL PARK TINGLEWOOD, -35.0030°S 116.6380°E, JUDD, S., 07-01-99, L10; C30070, MOUNT FRANKLAND NATIONAL PARK CROSSING BLOCK, -34.8030°S 116.8830°E, JUDD, S., 10-01-99, L10; C30071/2, KINGSTON ROAD, -34.0850°S 116 3500°E, JUDD, S., 24-01-99, L10, C31156, PORONGURUPS, -34.6667°S 117.8333°E, SPRINGETT, J A., 14-04-70, L41; C31157, GNANGARA, PINUS PINASTER PLANTATION, -31.7333°S 115 8333°E, SPRINGETT, J. A., 27-06-69, P1; C31158, ARTHUR RIVER, -33.3500°S 117.0333°E, CAR, C. A. & CAR, L. E , 16-08-92, R2; C31159, LEDGE POINT, -35.0167°S 118 0000°E, HUMPHREYS, W. F ET AL., 20-03-85; C31160, LUDLOW, -33.6167°S 115 4833°E, CLARKE, J., 05-06-24, S1; C31161, PEMBERTON HV84 MARRI RD, -34 5000°S 116.0833°E, SPRINGETT, J. A., 03-12-71; C31162, NORNALUP, -35.0000°S 116.8167°E, NICHOLLS COLLECTION, ??-??-38; C31163, POINT PERON, -32.3000°S 115 7000°E, KRN, MES (NICHOLLS COLLN), 30-08-33, R1; C31164, ROLEYSTONE, -32.1167°S 116.0667°E, NICHOLLS COLLECTION, 24-10-25, C31165, GOOSEBERRY HILL, -31 9500°S 116 0500°E, NICHOLLS COLLECTION, ??-06-32; C31166, PEMBERTON HL61 BIG BROOK 40, -34.2667°S 115.9333°E, SPRINGETT, J. A., 15-11-71; C31167, DWELLINGUP CX71 AMPHION 6, -32.7500°S 116 1667°E, SPRINGETT, J. A., 12-10-71; C31168, DWELLINGUP CY71, -32.7500°S 116.1667°E, SPRINGETT, J. A., 05-11-71; C31169, DWELLINGUP CX71 AMPHION 6, -32.7500°S 116.1667°E, SPRINGETT, J. A., 12-10-71, G30, C31170, PEMBERTON HV64 MARRI RD, -34 5000°S 116.0833°E, SPRINGETT, J. A., 03-12-71; C31171, MANJIMUP GY55 GRAY PINE CREEK RD, -34.2500°S 116 0000°E, SPRINGETT, J. A., 08-11-71, L10; C31172, GNANGARA, PINUS PINASTER PLANTATION, -31 7333°S 115 8333°E, SPRINGETT, J. A., 06-03-70, P1; C31173, PEMBERTON HV61, -34.5000°S 116 0000°E, SPRINGETT, J. A., 08-11-71, C31174/6, GLENEAGLE BW72 HAVEL'S PLOT 64, -32.2500°S 116.1667°E, SPRINGETT, J. A., 22-10-71, C31176, PEMBERTON HV61, -34 5000°S 116 0000°E, SPRINGETT, J A., 09-11-71; C31177, PEMBERTON HV64 MARRI RD, -34.5000°S 116.0833°E, SPRINGETT, J. A., 27-07-70; C31178, GLENEAGLE BY76 HAVEL'S PLOT 86, -32.2500°S 116.1667°E, SPRINGETT, J A., 22-10-71; C31179, GLENEAGLE BS86, -32.2500°S 116 1667°E, SPRINGETT, J. A., 28-10-71; C31180, GLENEAGLE BL87 HAVELS PLOT 169, -32.2500°S 116.1667°E, SPRINGETT, J. A., 18-10-71; C31161, MANJIMUP GY55 GRAY PINE CREEK RD, -34.2500°S 116 0000°E, SPRINGETT, J. A., 08-11-71; C31182, PEMBERTON HQ58 WARREN NATIONAL PARK, -34.4167°S 115 9167°E, SPRINGETT, J. A., 19-05-70, B10; C31183, GLENEAGLE BS86, -32 2500°S 116 1667°E, SPRINGETT, J A., 28-10-71; C31184, PEMBERTON HV64 MARRI RD, -34 5000°S 116 0833°E, SPRINGETT, J. A , 22-07-70; C31185/6, TWO PEOPLES BAY TICK FLAT MET. STAT. GULLY, -34.9833°S 118.1667°E, SPRINGETT, J. A., 22-05-70; C31187, PEMBERTON HV64 MARRI RD, -34.5000°S 116 0833°E, SPRINGETT, J. A., 03-12-71; C31188, PEMBERTON HL61 BIG BROOK, -34 2667°S 115.9333°E, SPRINGETT, J. A , ??-??-72; C31189, MANJIMUP, -34.2500°S 116 2500°E,

SPRINGETT, J A., 13-04-71, C31190, DWELLINGUP CX71 AMPHION 6, -32.7500°S 116.1667°E, SPRINGETT, J A., 12-10-71, C31191, GLENEAGLE BL68 HAVELS PLOT 166, -32.2500°S 116 1667°E, SPRINGETT, J. A, 18-10-71; C31192, PEMBERTON HL62 BIG BROOK 12, -34.2667°S 115.9333°E, SPRINGETT, J. A., 15-11-71; C31193, SHANNON HP81 MARCH RD SUTTON BLOCK, -34.6000°S 116.4000°E, SPRINGETT, J. A., 16-11-71; C31194, MUNDARING SW71 HAVEL'S PLOT 136, -32.0000°S 116 3333°E, SPRINGETT, J. A., 05-11-71; C31195, PEMBERTON HV64 MARRI RD, -34 5000°S 116 4167°E, SPRINGETT, J. A., 21-07-70; C31196, PEMBERTON HQ58 WARREN NATIONAL PARK, -34.4167°S 115 9167°E, SPRINGETT, J. A., 20-05-70, L10, C31197, TWO PEOPLES BAY TICK FLAT MET STATION, -34 9833°S 118 1667°E, SPRINGETT, J. A., 12-04-71; C31198, PEMBERTON HQ58 WARREN NATIONAL PARK, -34.4167°S 115.9167°E, SPRINGETT, J. A., 19-05-70, L41; C31199, PEMBERTON-VASSE, -34 4500°S 116 0333°E, SPRINGETT, J A., 23-09-71, B10, C31200, LOCALITY UNKNOWN, ??S ??E, COLLECTOR UNKNOWN, ??-??-??; C31201, GLENEAGLE BO68 HAVELS PLOT 171, -32 2500°S 116 1667°E, SPRINGETT, J. A., 22-10-71, S1; C31202, TWO PEOPLES BAY TICK FLAT NSB PAST HUT, -34 9833°S 118 1667°E, SPRINGETT, J A., 22-05-70; C31203, GNOOCARDUP SEEP LEEUWIN NATURALISTE NATIONAL PARK W EDGE, -33.9333°S 115.0000°E, SLACK-SMITH, S , 26-11-85, L90; C31204/5, GNOOCARDUP SEEP LEEUWIN NATURALISTE NATIONAL PARK, -33 9333°S 115.0000°E, SLACK-SMITH, S., 26-11-85, L50; C31206, GNOOCARDUP, -33.9333°S 115 0000°E, SLACK-SMITH, S , 04-08-85; C31207/8, TORNDIRRUP NATIONAL PARK 9 KM S. OF ALBANY, -35 0900°S 117 8333°E, DYER, P. H. & LYON, J L , 09-11-83, P1, C31209, VALLEY OF THE GIANTS E SIDE EXIT FROM LARGE TINGLE TREE ROAD, -35 0000°S 116 8667°E, FRIEND, J. A., 11-06-81, L10; C31210, ARALUEN, -32.1250°S 116.1000°E, GLEN FOREST HIGH SCHOOL BIOLOGY, ??-08-72, A30; C31211/6, MT COOKE, -32.4167°S 116 3000°E, HARVEY, M. S. & WALDOCK, J. M., 15-05-91, P3; C31217, MT COOKE NEAR SUMMIT, -32 4167°S 116 3000°E, HARVEY, M. S., WALDOCK, J. M. & PETERSON, M., 07-08-90, C31218, PERTH AIRPORT, -31.9233°S 115 9778°E, HUMPHREYS, W F. ET AL., ??-12-86, C31219, TRIGG E SIDE OF OLD WEST COAST H'WAY, -31 8833°S 115.7530°E, WALDOCK, J. M., 29-08-93, L10; C31220, NINDUP W OF WITCHCLIFFE, -34 0500°S 115 0500°E, WALDOCK, J. M., 06-02-93, L41; C31221, SOUTH COAST HIGHWAY 7 KM N, -34 9333°S 117.3667°E, HARVEY, M. S & WALDOCK, J M., 26-04-90, B10; C31222, THE CASCADES 8 KM SSW PEMBERTON, -34.5000°S 116.0000°E, HARVEY, M. S. & WALDOCK, J. M., 03-05-90, B10; C31223, YORK 10 KM SW, -31.9500°S 116.5167°E, BANNISTER, J., 15-08-93, L10; C31224, GNOOCARDUP, -33.9333°S 115.0000°E, SLACK-SMITH, S., 04-08-85; C31225, SHANNON NATIONAL PARK DOG POOL ON SHANNON RIVER, -34.7667°S 116 3667°E, WALDOCK, J. M. & SAMPEY, A., 09-06-93, L20; C31226, SHANNON NATIONAL PARK DOG POOL ON SHANNON RIVER, -34.7667°S 116.3667°E, HARVEY, M. S. & WALDOCK, J. M., 30-04-90; C31227, LAKE POORGINUP, -34.5500°S 118.7333°E, HARVEY, M. S. & WALDOCK, J. M., 24-04-90; C31228, LAKE POORGINUP, -34.5500°S 116.7333°E, HARVEY, M. S. & WALDOCK, J. M., 24-04-90; C31229, LAKE POORGINUP, -34.5500°S 116.7333°E, HARVEY, M. S. & WALDOCK, J. M., 24-04-90, C31230, PORONGURUP NATIONAL PARK S END OF MILLINUP PASS, -34.7000°S 117.9000°E, HARVEY, M. S. & WALDOCK, J. M., 31-03-93, L10; C31231, TWO PEOPLES BAY TICK FLAT WEATHER STATION, -34.9833°S 118 1667°E, SPRINGETT, J. A., 22-05-70; C31232, WALPOLE CAMP SITE, -34.9833°S 116.7167°E, NICHOLLS COLLECTION, 08-01-33; C31233, POINT PERON, -32.3000°S 115 7000°E, NORRIS, R., 30-05-32; C31234, MULLALOO 6 KM AT 15 DEG FROM MULLALOO BEACH, -31 8000°S 115.7333°E, CHAPMAN, A. & HOW, R., 17-09-78, P1; C31235, DEVIL'S LAIR DOLINE WI-61, -34.1500°S 115.0667°E, BAYNES, A., 06-01-94; C31236, TORNDIRRUP NATIONAL PARK GULLY OUTSIDE N EDGE ON LIMEBURNERS RD, -35.0833°S 117.9000°E, HARVEY, M. S. & WALDOCK, J M , 26-03-93, L10; C31237, LEDGE POINT, -35 0187°S 118.0328°E, HUMPHREYS, W F. ET AL., 20-03-85; C31238, TWO PEOPLES BAY TICK FLAT HUT, -34.9833°S 118.1667°E, SPRINGETT, J. A., 12-04-71; C31239, GLENBOURNE FARM OLD ELLENSBROOK ROAD NEAR MARGARET RIVER, -33 9167°S 115.0167°E, MARSH, L. ET AL., 31-03-97, P2; C31240, GLENBOURNE FARM OLD ELLENSBROOK ROAD NEAR MARGARET RIVER, -33.9167°S 115.0167°E, MARSH, L. ET AL., 29-12-97, P2; C31241, WALPOLE ROAD TO WALPOLE NEAR LAND LEACH GULLY, -34.9833°S 116.7167°E, NICHOLLS COLLECTION, 23-11-38; C31242, SWARBRICK'S TRACK VIA ALBANY, -35.0000°S 116.8167°E, NICHOLLS COLLECTION, 03-01-33; C31243, MT GAIRDNER TWO PEOPLES BAY, -35 0000°S 118.1833°E, MUELLER, O., 23-06-98, R2, C31244, 4.75 KM ESE OF MARGARET RIVER, -33.9644°S 115.1228°E, PETERSON, M., 14-02-92; C31245, MT LESUEUR 5 5 KM NNE, -30 1333°S 115.2000°E, UWA, 10-07-89, G30; C31246, MT LESUEUR 5 5 KM NNE, -30.1333°S 115.2000°E, UWA, 10-07-89; C31247, MT LESUEUR 1 6 KM N, -30 1667°S 115.2000°E, UWA, 11-07-89; C31248/51, MT LESUEUR 3 KM NEE, -30.1667°S 115 2333°E, UWA, 11-07-89, C31252, MT LESUEUR 2.5 KM NE, -30 1667°S 115.2000°E, UWA, 11-07-89; C31253, MT LESUEUR 4.5 KM E, -30.1667°S 115 2500°E, UWA, 12-07-89, C31254, MT PERON 5 5 KM E, -30 1167°S 115.2000°E, UWA, 11-07-89, R1; C31255, MT PERON 7 KM E, -30.1167°S 115 2333°E, UWA, 11-07-89; C31256, STIRLING RANGE NATIONAL PARK BESIDE CREEK NEAR START OF WALK TRACK TO TOOLNRUNUP PEAK, -34 4000°S 118.0667°E, FRIEND, J. A., 10-06-81, L10, C31257, LAKE SMITH LAKE AND PEATY SHRUBLAND NEXT TO LAKE, -34 4300°S 115.7267°E, HORWITZ, P ET AL., ??-10-94, A10; C31258, JOONDALUP EDITH COWAN UNIVERSITY CAMPUS, -31.7550°S 115.7833°E, JUDD, S., ??-03-99, P3; C31259, DRYANDRA NATURE RESERVE, -32.7333°S 116 9500°E, NORWOOD, C., 03-02-00, B20; C31260, MT DALE WITHIN 300M OF SUMMIT, -32.1333°S 116.3000°E, JUDD, S , 29-03-00, L40; C31261, MT DALE WITHIN 300M OF SUMMIT, -32 1333°S 116 3000°E, JUDD, S., 29-03-00, L10; C31262, MT DALE WITHIN 300M OF SUMMIT, -32.1333°S 116.3000°E, JUDD, S., 29-03-00, G30; C31263, WALPOLE NORNALUP NATIONAL PARK TINGLE CREEK FOREST, -34 9583°S 116.8000°E, VAN HEURCK, P. ET AL , 14-05-97, L40; C31264/5, GLENBOURNE FARM OLD ELLENSBROOK ROAD NEAR MARGARET RIVER, -33 9167°S 115 0167°E, MARSH, L. ET AL., 26-10-98, P2, C31266/7, ALBANY WINDFARM, -35 0519°S 117.7553°E, TEALE, R., 19-03-99, P3; C31284, CRAWLEY PELICAN POINT, -31.9633°S 115.8167°E, COLLECTOR UNKNOWN, 24-03-23; C31285, NORNALUP SWARBRICK'S TRACK, -35 0000°S 116.8167°E, NICHOLLS COLLECTION, 03-01-33, C31286, WATERMANS BAY 2 MILES NORTH, -31 8167°S 115.7500°E, NICHOLLS COLLECTION, ??-12-32; C31287/8, SWARBRICK'S TRACK VIA ALBANY, -35 0000°S 116.8167°E, NICHOLLS COLLECTION, 04-01-33; C31839, LANDSDALE SCHOOL, -31.8206°S 115 8503°E, HARVEY, M. S & WALDOCK, J. M., 28-11-95, P3, C31840, WOODMAN POINT, -32.1297°S 115.7564°E, WALDOCK, J. M. & LONGBOTTOM, A. F., 01-09-94, P3, C31841, WOODMAN POINT, -32.1328°S 115.7581°E, HARVEY, M. S. & WALDOCK, J. M., 06-07-95, P3; C31842, WOODMAN POINT, -32.1328°S

115 7581°E, WALDOCK, J. M & LONGBOTTOM, A. F., 01-09-94, P3; C31843, WOODMAN POINT, -32.1328°S 115 7581°E, WALDOCK, J. M & LONGBOTTOM, A. F., 04-11-94, P3, C31844, TUART HILL, -31 8803°S 115.8583°E, WALDOCK, J. M. ET AL., 23-09-93, P3; C31845, MT HENRY, -32 0314°S 115 8622°E, HARVEY, M. S. & WALDOCK, J. M., 14-01-95, P3; C31846, TRIGG DUNE BUSH, -31 8692°S 115 7606°E, HARVEY, M. S & WALDOCK, J. M., 25-09-95, P3; C31847, TRIGG DUNE BUSH, -31 8692°S 115.7606°E, HARVEY, M. S. & WALDOCK, J. M., 29-01-96, P3; C31848, BOLD PARK, -31.9372°S 115 7711°E, HARVEY, M. S. & WALDOCK, J. M., 19-05-94, P3; C31849, PERTH AIRPORT, -31 9767°S 115 9744°E, WALDOCK, J M ET AL., 23-09-93, P3; C31850, PERTH AIRPORT, -31 9767°S 115 9744°E, WALDOCK, J. M., GOODSELL, J. & WEBB, J., 06-01-94, P3, C31851, MT CLAREMONT, -31 9611°S 115.7667°E, WALDOCK, J. M. & LONGBOTTOM, A. F., 01-09-94, P3, C31852, MT CLAREMONT, -31.9611°S 115 7667°E, WALDOCK, J. M. & HARVEY, M. S., 06-07-95, P3; C31853, TALBOT ROAD RESERVE, -31 8681°S 116.0511°E, WALDOCK, J. M. & HARVEY, M S., 24-06-93, P3; C31867, WOODMAN POINT, -32.1306°S 115 7578°E, WALDOCK, J. M. & LONGBOTTOM, A. F., 04-11-94, P3.

3.16.1. PHILOSCIIDAE SPECIES 1

Plate 3.4, Gm 4.6; Plate 3.17, Pe 1.13; Plate 3.67

MATERIAL EXAMINED: C31277, MT COOKE, -32.4167°S 116.3000°E, HARVEY, M. S. & WALDOCK, J. M., 31-07-91, L10; C31278, MT COOKE, BASE OF MOUNT COOKE, -32 4167°S 116.3000°E, HARVEY, M. S., WALDOCK, J M & PETERSON, M., 07-08-90; C31279, MT COOKE, -32 4167°S 116.3000°E, HARVEY, M. S. & WALDOCK, J. M., 16-06-91, P3; C31280/1, MT COOKE, -32.4167°S 116.3000°E, HARVEY, M. S & WALDOCK, J. M., 31-07-91, P3; C31282, ARMADALE, -32.1500°S 116.0000°E, NICHOLLS COLLECTION, ??-11-34; C31283, ARMADALE, -32.1500°S 116.0000°E, COLLECTOR UNKNOWN, 18-06-32; C31854, TUART HILL, -31 8806°S 115.8589°E, HARVEY, M S & WALDOCK, J. M., 20-07-93, P3, C31855, BRICKWOOD RESERVE, CARDUP, -32.2339°S 116.0019°E, WALDOCK, J. M., WEST, P. L. & LONGBOTTOM, A., 17-06-96, P3; C31856, BRICKWOOD RESERVE, CARDUP, -32.2333°S 116 0006°E, WALDOCK, J. M., WEST, P. L. & LONGBOTTOM, A., 17-06-96, P3, C31857, RUSHTON ROAD, -32.0639°S 116 0189°E, WALDOCK, J. M., WEST, P. L. & LONGBOTTOM, A., 17-06-96, P3; C31858, BUSHMEAD, -31 9197°S 116.0169°E, WALDOCK, J M., WEST, P. L. & LONGBOTTOM, A., 17-06-96, P3; C31859, HEPBURN HEIGHTS, -31.8172°S 115 7703°E, WALDOCK, J M & HARVEY, M S., 25-09-95, P3; C31860, NORMAN ROAD, CARDUP, -32.2636°S 116.0036°E, WALDOCK, J. M., WEST, P. L. & LONGBOTTOM, A., 17-06-96, P3; C31861, NORMAN ROAD, CARDUP, -32 2672°S 116.0122°E, WALDOCK, J. M., WEST, P L & LONGBOTTOM, A., 17-06-96, P3; C31862, CARDUP RESERVE, -32.2481°S 115 9856°E, WALDOCK, J. M., WEST, P L & LONGBOTTOM, A., 17-06-96, P3; C31863, PERTH AIRPORT, -31.9761°S 115.9736°E, WALDOCK, J. M. ET AL., 24-06-93, P3; C31864, TALBOT ROAD RESERVE, -31 8733°S 116.0478°E, WALDOCK, J. M & HARVEY, M. S., 28-07-93, P3; C31865, TALBOT ROAD RESERVE, -31 8733°S 116.0478°E, WALDOCK, J. M. ET AL., 18-11-93, P3; C31866, TALBOT ROAD RESERVE, -31.8733°S 116.0478°E, WALDOCK, J. M. ET AL., 23-09-93, P3.

Diagnosis: Habitus runner/creeper. Animal small (< 5mm) and convex. Pereonites with numerous but very small setae.

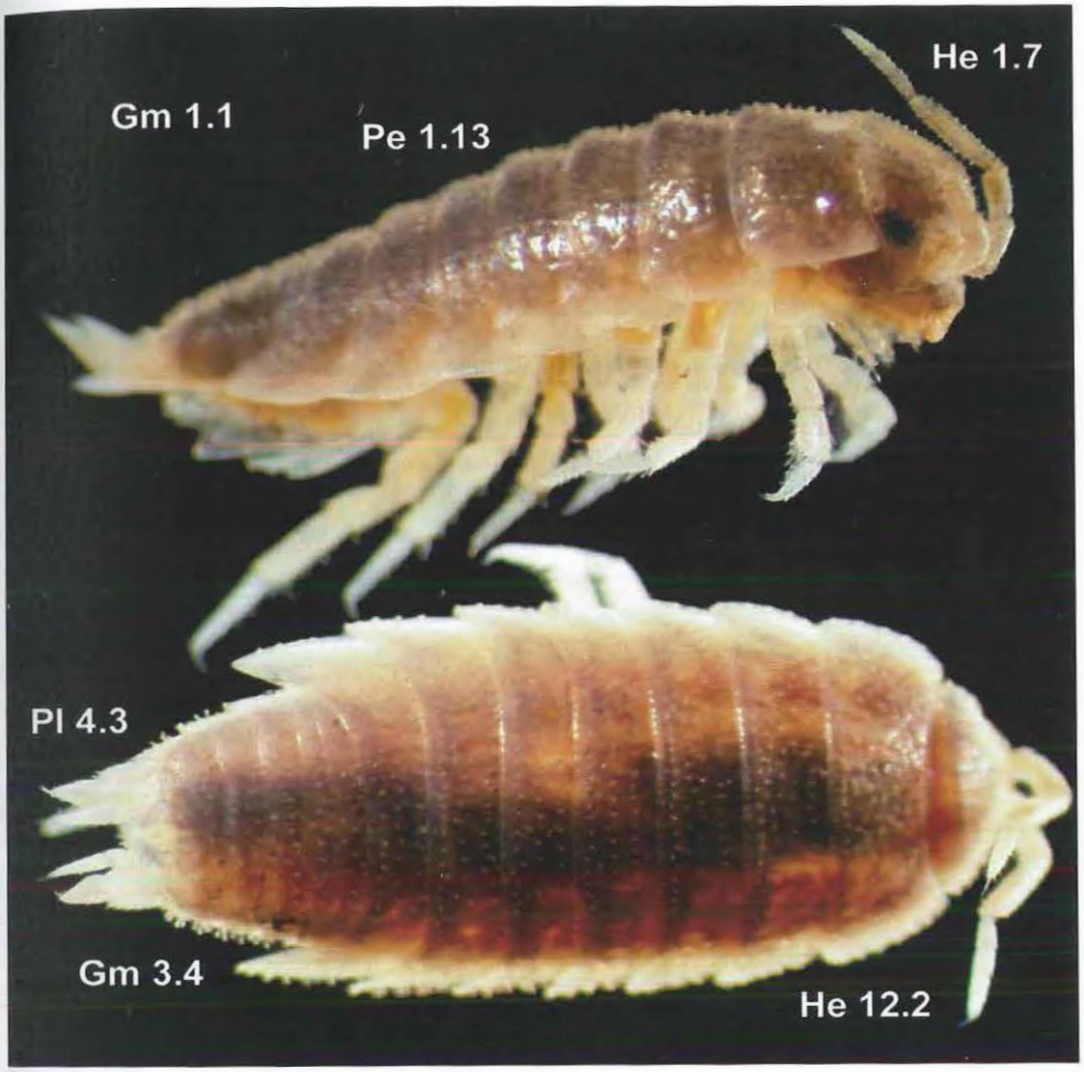


Plate 3.67. Philosciidae species 1 from Brickwood Reserve, Cardup (C31856) (length 3.5 mm).

3.16.2. PHILOSCIIDAE SPECIES 2

Plate 3.68

MATERIAL EXAMINED: C30073/7, SALT LAKE (NORTH OF JURIEN BAY), -30.1880°S 115.0200°E, JUDD, S., 14-10-98, S1; C30078, SALT LAKE (NORTH OF JURIEN BAY), -30.1880°S 115.0200°E, JUDD, S., 14-10-98, R5; C30079, NAMBUNG NATIONAL PARK LAKE THETIS, -30.5070°S 115.0820°E, JUDD, S., 16-10-98, L10.

Diagnosis: Habitus runner/creeper. Animal amphibious, convex, small (< 5 mm) long and thin with very pale colouring giving a translucent look. Found in or near salt water.

Remarks: On collection this species appeared to be amphibious. To test this theory, and in the manner of Nicholls (see Nicholls and Barnes 1926a), one of the specimens (C30073/7) was kept in a sample of fresh water. It was still alive twenty-four hours later.

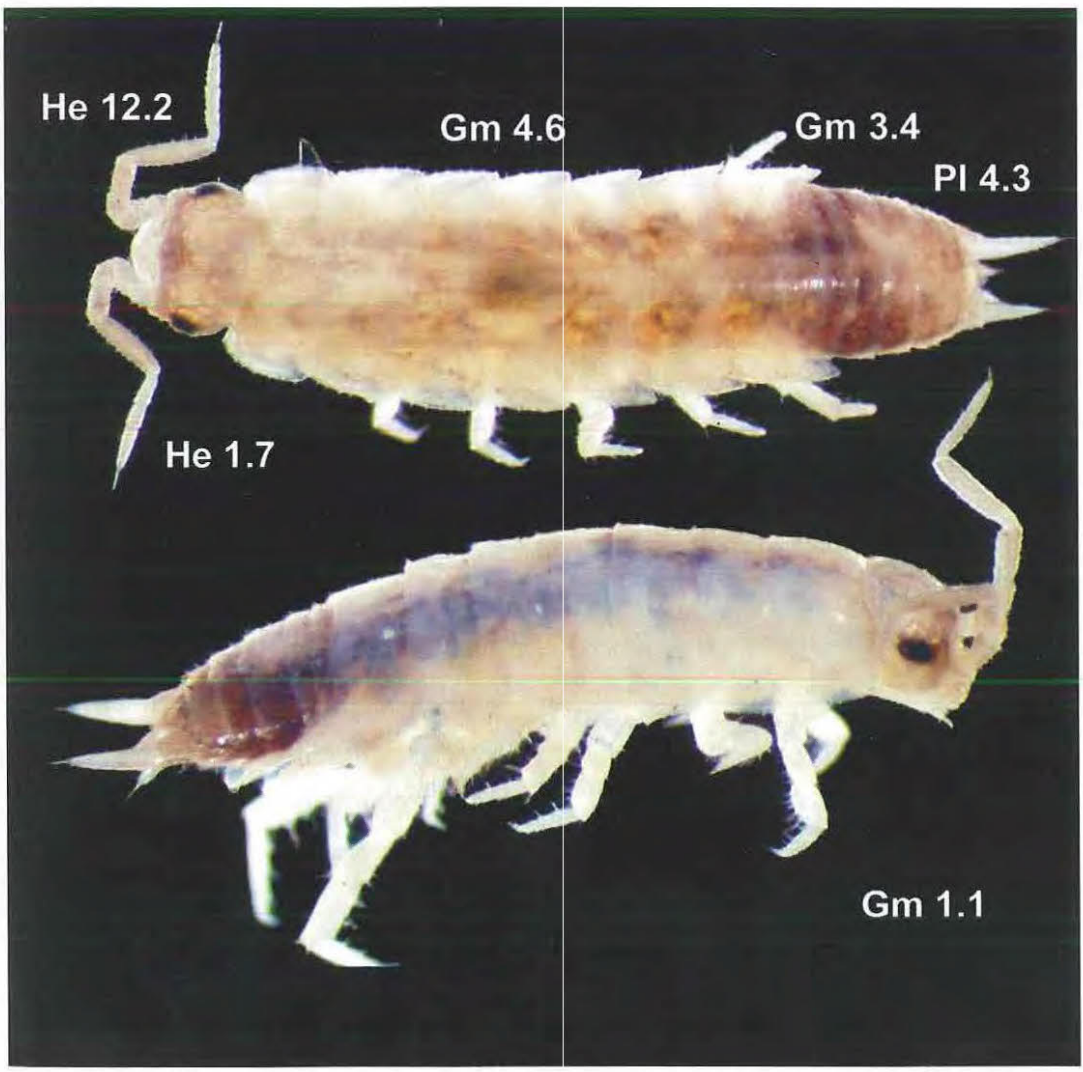


Plate 3.68. Philosciidae species 2 from a salt lake north of Jurien Bay (C30073) (length 4.5 mm).

3.16.3. EURYGASTOR NEW SPECIES

Plate 3.1, Gm .1.1; Plate 3.34, Pl 1.3; Plate 3.37, Pl 4.3; Plate 3.69

Eurygastor sp. Springett, 1976

?Eurygastor sp Judd & Horwitz, 2003

MATERIAL EXAMINED: C11018, GLENEAGLE BL68 HAVEL'S PLOT 168, -32.2500°S 116.1667°E, SPRINGETT, J. A., 18-10-71; C30080, MONADNOCKS CONSERVATION PARK MILLARS LOG ROAD, -32 3950°S 116.3350°E, JUDD, S , 05-11-98, L40; C30081/2, LEONA ROAD, -32.2180°S 116.3250°E, JUDD, S , 23-07-98, L10. C30083, MONADNOCKS CONSERVATION PARK MILLARS LOG ROAD, -32.3950°S 116 3350°E, JUDD, S., 05-11-98, L10; C30084, SCHULSTAAD ROAD CREEK, -32 2800°S 116 3600°E, JUDD, S , 05-11-98, L60; C30085, MULLALYUP CONSERVATION PARK, -33 7150°S 115.8680°E, JUDD, S., 03-12-98, L30; C30086, MULLALYUP CONSERVATION PARK, -33.7150°S 115.8680°E, JUDD, S., 03-12-98, L10; C30087/8, LEEUWIN NATURALISTE NATIONAL PARK KARRI NEAR HAMELIN BAY, -34 2000°S 115.0720°E, JUDD, S , 10-12-98, L10, C30089, PORONGORUP NATIONAL PARK BOLGANUP DAM, -34.6700°S 117.8820°E, JUDD, S , 16-12-98, L10, C30090/2, PORONGORUP NATIONAL PARK WANSBROUGH WALK, -34 6830°S 117.8480°E, JUDD, S., 16-12-98, L10, C30093, WEST CAPE HOWE NATIONAL PARK, -35.0820°S 117.6430°E, JUDD, S., 17-12-98, B10; C30094, WEST CAPE HOWE NATIONAL PARK, -35 0820°S 117.6430°E, JUDD, S., 17-12-98, L42; C30095, WEST CAPE HOWE NATIONAL PARK, -35.0820°S 117 6430°E, JUDD, S., 17-12-98, L10; C30096, TORNDIRRUP NATIONAL PARK, -35 1150°S 117 9330°E, JUDD, S., 18-12-98, L10; C30097/100, PARDELUP NATURE RESERVE, -34.6720°S 117 4150°E, JUDD, S., 20-12-98, L10, C30101, MOUNT DALE, -32 1259°S 116.2951°E, WATSON, A , 01-10-01, P3; C30102, MOUNT DALE, -32.1259°S 116.2951°E, JUDD, S. & WATSON, A , 26-06-01, G10; C30103/4, MOUNT DALE, -32.1011°S 118 2875°E, JUDD, S. & WATSON, A., 14-10-01, G10, C30105, MOUNT DALE, -32 0918°S 116.2779°E, JUDD, S & WATSON, A., 26-06-01, G10; C30106/7, MOUNT DALE, -32.0878°S 116.2784°E, JUDD, S. & WATSON, A , 11-10-01, G10; C30108, MOUNT DALE, -32 0869°S 118.2928°E, WATSON, A., 01-10-01, P3; C31268, ELLEN BROOK PATH TO MEEKADORABBIE CREEK, -33.9167°S 115 0000°E, SLACK-SMITH, S., 27-11-85, L10; C31269, MARGARET RIVER BURNSIDE ROAD, NORTH OF MARGARET RIVER, -33.9167°S 115 0500°E, HARVEY, M. S., 19-04-92, B10; C31270, PORONGURUP NATIONAL PARK S END OF MILLINUP PASS, -34.6953°S 117 6975°E, HARVEY, M. S., 02-09-96, P3; C31271, STIRLING RANGE NATIONAL PARK MT. MAGOG, -34.3997°S 117.9431°E, WALDOCK, J. M. & MAIN, B. Y , 03-09-96, P3; C31272, STIRLING RANGE NATIONAL PARK TALYUBERLUP PICNIC SITE, -34 4156°S 117.9550°E, WALDOCK, J. M. & MAIN, B. Y., 03-09-96, P3; C31273, STIRLING RANGE NATIONAL PARK TOOLBRUNUP PEAK TRACK, -34.3922°S 118.0589°E, WALDOCK, J. M. & MAIN, B Y., 03-09-96, P3; C31274, STIRLING RANGE NATIONAL PARK TOOLBRUNUP PEAK TRACK, -34 4000°S 118.0667°E, WALDOCK, J. M. & SAMPEY, A , 10-06-93, L10; C31275, STIRLING RANGE NATIONAL PARK TOOLBRUNUP PEAK TRACK, -34.4000°S 118.0667°E, HARVEY, M S., 02-04-93, L10, C31276, WALPOLE NORNALUP NATIONAL PARK KARRI FOREST, -34.9833°S 116 7083°E, VAN HEURCK, P. ET AL., 13-05-97, B40.

Diagnosis: Habitus runner. Animal of relatively large size (~8 mm) with strong colouring of pale cream and brown. Fully terrestrial. Pleonal epimera 3, 4 & 5 extended creating stepped outline on lateral margin of pleonites in dorsal view.

Remarks: The pleon is also shorter than Laevophiloscia. Determinations of this genus are made by comparison with specimens determined by Vandel (C11018). See Vandel, (1973a, p. 47) and also Springett, (1976, p. 82).

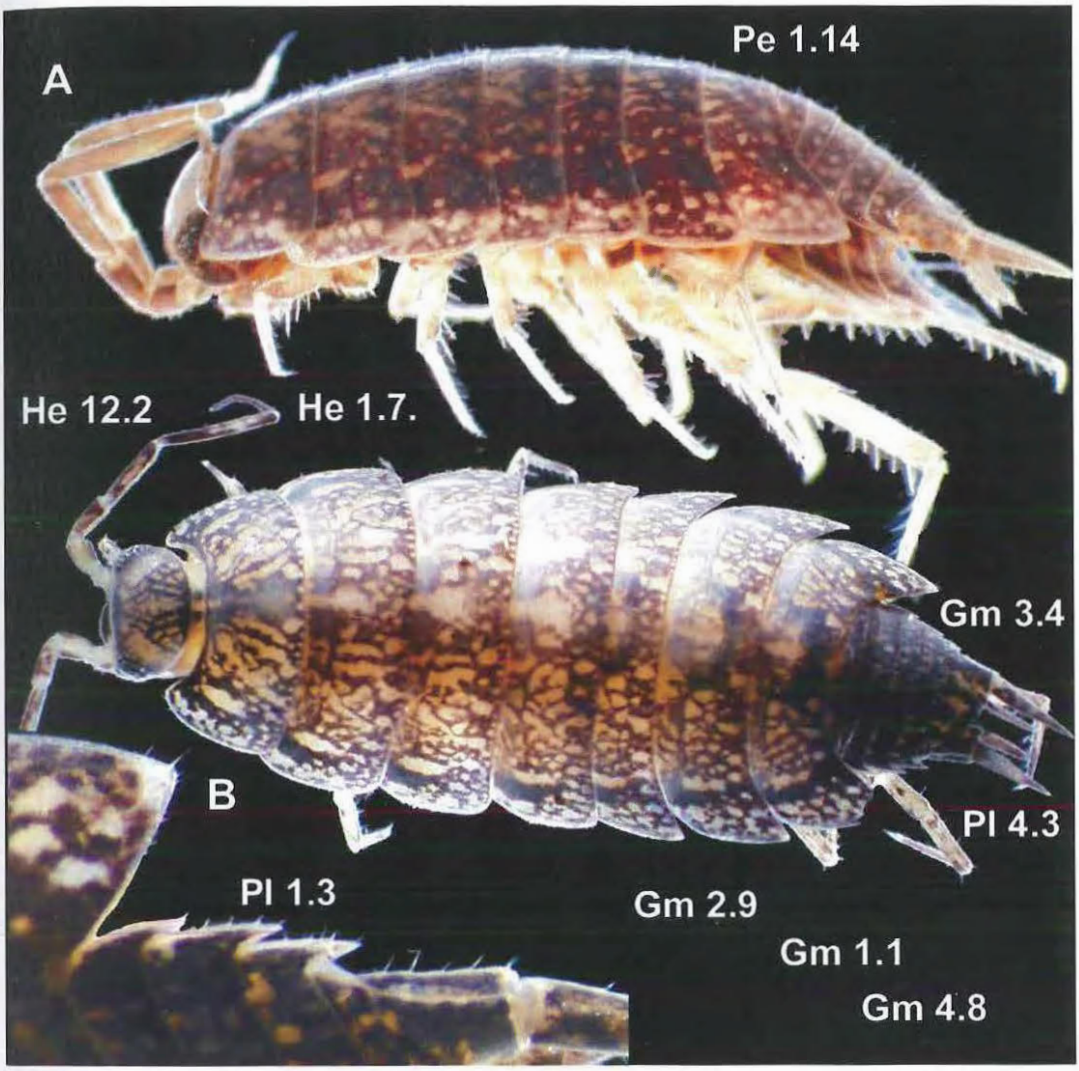


Plate 3.69. Eurygastor **new species from (A) Stirling Range National Park (C31275) and (B) Leeuwin Naturaliste National Park (C30087) (length 8 mm).**

3.16.4. GENUS LAEVOPHILOSCIA WAHRBERG

Diagnosis: A diagnosis based on mouthparts was given by Wahrberg (1922). This was repeated by Vandel (1973a) together with a discussion of the character of the number and the noduli laterales. Since these have not been examined in great detail at this stage and also because the work of Vandel was problematic in respect to the arrangement of the noduli laterales, (see Subsection 3.2.3) specimens without the character of the extended pleura and the two distinct taxa previously mentioned are considered to be Laevophiloscia. It should be noted that the Philosciid genus Plymophiloscia has also been noted from the region (Storey, Halse & Sheil, 1993) and that due to: (1) the inadequate state of the taxonomy of this group; (2) the time required to dissect and examine the range of characters needed; (3) the need for type material and its likely age and condition; and, (4) the sheer amount of material collected, limited work on this genus was undertaken during this study. Diagnosis of the two taxa identifiable here using very general characters are therefore tentative. Both taxa definitely include a number of species. In this respect, synonymies with species so far described are not possible.

3.16.4.1. Laevophiloscia species 1

Plate 3.2, Gm 2.8; Plate 3.3, Gm 3.4; Plate 3.4, Gm 4.7; Plate 3.5, He 1.7; Plate 3.17, Pe 1.14; Plate 3.21, Pe 5.1; Plate 3.34, Pl 1.4; Plate 3.35, Pl 1.22; Plate 3.70.

Laevophiloscia sp. 1 Judd & Horwitz, 2003

MATERIAL EXAMINED: C30109/10, MOUNT DALE, -32 1011°S 116.2875°E, JUDD, S. & WATSON, A., 14-10-01, G10; C30111/13, MOUNT DALE, -32.0899°S 116 2961°E, JUDD, S & WATSON, A., ??-??-01, G10; C30114, MOUNT DALE, -32.1071°S 116.2848°E, WATSON, A., 01-10-01, P3; C30115, MOUNT DALE, -32.1028°S 116.2861°E, JUDD, S. & WATSON, A., 26-06-01, G10; C30116/7, MOUNT DALE, -32.0918°S 116.2779°E, JUDD, S. & WATSON, A , 26-06-01, G10; C30118/20, MOUNT DALE, -32.0878°S 116.2784°E, JUDD, S. & WATSON, A., 11-10-01, G10; C30121, MOUNT DALE, -32.0834°S 116 2831°E, WATSON, A., 01-10-01, P3; C30122/28, MOUNT DALE, -32.0834°S 116.2831°E, JUDD, S. & WATSON, A., 14-12-01, G10; C30129/32, MOUNT DALE, -32.0885°S 116.2810°E, JUDD, S & WATSON, A., 11-10-01, G10; C30133, MOUNT DALE, -32.0992°S 116.2851°E, WATSON, A., 01-10-01, P3, C30134, MOUNT DALE, -32.1062°S 116.2815°E, WATSON, A., 01-10-01, P3; C30135, MOUNT DALE, -32 1120°S 116.2875°E, WATSON, A., 01-10-01, P3; C30136, DRYANDRA (LIONS VILLAGE), -32.7870°S 116 9820°E, JUDD, S., 07-09-98, L10; C30137, DRYANDRA (LIONS VILLAGE), -32.7870°S 116.9820°E, JUDD, S., 07-09-98, L42, C30138, DRYANDRA (LIONS VILLAGE), -32.7870°S 116 9820°E, JUDD, S., 07-09-98, G10; C30139/40, DRYANDRA (LIONS VILLAGE), -32.7870°S 116.9820°E, JUDD, S., 07-09-98, L10; C30141/42, JAM HILL NATURE RESERVE, -30 8660°S 115 8020°E, JUDD, S., 02-10-98, L10; C30143, JAM HILL NATURE RESERVE, -30.8660°S 115 8020°E, JUDD, S , 02-10-98, L20; C30144, MOGANMOGANNING NATURE RESERVE, -31.1200°S 116.2530°E, JUDD, S., 11-10-98, G40, C30145, MOGANMOGANNING NATURE RESERVE, -31 1200°S 116.2530°E, JUDD, S., 11-10-98, L10, C30146, MOGANMOGANNING NATURE RESERVE, -31 1200°S 116 2530°E, JUDD, S., 11-10-98, R1; C30147, MOGANMOGANNING NATURE RESERVE, -31 1200°S 116.2530°E, JUDD, S , 11-10-98, G30; C30148, SEVEN MILE WELL NATURE RESERVE, -31.0650°S 116.2020°E, JUDD, S., 11-10-98, R2; C30149, SEVEN MILE WELL NATURE RESERVE, -31.0650°S 116 2020°E, JUDD, S , 11-10-98, R1; C30150, SEVEN MILE WELL NATURE RESERVE, -31.0650°S 116.2020°E, JUDD, S., 11-10-98, G30; C30151, WANNAMAL LAKES NATURE RESERVE, -31.0750°S 116.0470°E, JUDD, S., 11-10-98, G40; C30152, WANNAMAL LAKES NATURE RESERVE, -31.0750°S 116.0470°E, JUDD, S., 11-10-98, G30; C30153, WANNAMAL LAKES NATURE RESERVE, -31.0750°S 116.0470°E, JUDD, S., 11-10-98, R1; C30154/6, WANNAMAL LAKES NATURE RESERVE, -31.0750°S 116 0470°E, JUDD, S., 11-10-98, G30; C30157, HILL RIVER NATIONAL PARK, -30 3030°S 115.1830°E, JUDD, S., 14-10-98, B30, C30158, HILL RIVER NATIONAL PARK, -30.3030°S 115.1830°E, JUDD, S., 14-10-98, L10; C30159, HILL RIVER NATIONAL PARK, -30.3030°S 115.1830°E, JUDD, S., 14-10-98, R1; C30160/1, NAMBUNG NATIONAL PARK, -30 5420°S 115.1430°E, JUDD, S., 15-10-98, L40; C30162, NAMBUNG NATIONAL PARK, -30.5420°S 115 1430°E, JUDD, S., 15-10-98, G30, C30163, WONGONDERRAH NATURE RESERVE, -30.5600°S 115.3580°E, JUDD, S., 15-10-98, L60, C30164, WONGONDERRAH NATURE RESERVE, -30 5600°S 115.3580°E, JUDD, S., 15-10-98, G40, C30165, WONGONDERRAH NATURE RESERVE, -30 5600°S 115 3580°E, JUDD, S., 15-10-98, G30, C30166, MOORE RIVER STATE FOREST, -31.1400°S 115.4750°E, JUDD, S , 16-10-98, L10; C30167, MOOLIABEENEE ROAD (C42743), -31.3480°S 115.9950°E, JUDD, S., 18-10-98, R3; C30168, MOUNT BYROOMANNING NR, -31.3730°S 116.1270°E, JUDD, S., 18-10-98, R2, C30169, MOUNT BYROOMANNING NR, -31 3730°S 116.1270°E, JUDD, S., 18-10-98, L10; C30170, CLACKLINE NATURE RESERVE, -31.7000°S

116 4830°E, JUDD, S., 20-10-98, G30; C30171, ST RONANS NATURE RESERVE, -31 8730°S 116 6400°E, JUDD, S., 21-10-98, L10; C30172, STRANGE ROAD NATURE RESERVE, -32 4030°S 116.6150°E, JUDD, S , 26-10-98, L20; C30173, JINGALUP NATURE RESERVE, -34 0130°S 117 0130°E, JUDD, S , 29-10-98, L42; C30174/5, JINGALUP NATURE RESERVE, -34 0130°S 117 0130°E, JUDD, S., 29-10-98, G30, C30176, JINGALUP NATURE RESERVE, -34 0130°S 117 0130°E, JUDD, S., 29-10-98, R1; C30177, NARLINGUP NATURE RESERVE, -33 8630°S 116.8900°E, JUDD, S , 29-10-98, G30, C30178, NARLINGUP NATURE RESERVE, -33 8530°S 116 8900°E, JUDD, S., 29-10-98, L10; C30179, NARLINGUP NATURE RESERVE, -33 8630°S 116 8900°E, JUDD, S., 29-10-98, G30; C30180, BOOLADING NATURE RESERVE, -33 3500°S 116 6270°E, JUDD, S., 30-10-98, G30, C30181, PROPOSED LANE POOLE EXTENSION, -33.2030°S 116.4630°E, JUDD, S , 30-10-98, L20; C30182, PROPOSED LANE POOLE EXTENSION, -33 2030°S 116.4630°E, JUDD, S , 30-10-98, G40, C30183, MONADNOCKS CONSERVATION PARK MARGINATA ROAD, -32.2420°S 116.2050°E, JUDD, S , 04-11-98, G10; C30184, KEN ROAD STATE FOREST, -32 5320°S 116 2850°E, JUDD, S., 06-11-98, L20; C30185, HOTHAM RIVER (UPPER SLOPES), -32 9170°S 116.3820°E, JUDD, S , 11-11-98, L10; C30186, HOTHAM RIVER (UPPER SLOPES), -32.9170°S 116 3820°E, JUDD, S , 11-11-98, L20, C30187, HOTHAM RIVER (UPPER SLOPES), -32.9170°S 116.3820°E, JUDD, S , 11-11-98, G30, C30188, PINDALUP ROAD/ N.E. ROAD, -32 6000°S 116 2000°E, JUDD, S , 11-11-98, G30; C30189, PINDALUP ROAD/ N E. ROAD, -32.6000°S 116 2000°E, JUDD, S., 11-11-98, G20, C30190, PINDALUP ROAD/ N.E. ROAD, -32.6000°S 116.2000°E, JUDD, S , 11-11-98, L20; C30191, BULLER NATURE RESERVE, -32 8770°S 115.8300°E, JUDD, S., 12-11-98, L10; C30192, BULLER NATURE RESERVE, -32 8770°S 115 8300°E, JUDD, S., 12-11-98, L20; C30193, BULLER NATURE RESERVE, -32 8770°S 115 8300°E, JUDD, S., 12-11-98, L10; C30194, AUSTIN BAY NATURE RESRVE, -32.6380°S 115.7720°E, JUDD, S , 12-11-98, E1; C30195, BATALLING STATE FOREST, -33 3330°S 118.4730°E, JUDD, S , 23-11-98, L10; C30196, BATALLING STATE FOREST, -33.3330°S 116.4730°E, JUDD, S , 23-11-98, L10, C30198, CHALK BROOK (LANE POOLE RESERVE), -33 0870°S 115.2320°E, JUDD, S., 26-11-98, L10; C30199, CHALK BROOK (LANE POOLE RESERVE), -33 0670°S 118.2320°E, JUDD, S., 26-11-98, L50; C30200, CHALK BROOK (LANE POOLE RESERVE), -33 0670°S 116 2320°E, JUDD, S., 26-11-98, L20; C30201/2, FALLS CREEK NATURE RESERVE, -33 0650°S 116.0150°E, JUDD, S., 26-11-98, L10, C30203, PORONGORUP NATIONAL PARK WANSBROUGH WALK, -34.6830°S 117.8480°E, JUDD, S., 16-12-98, L10, C30204, MILLBROOK NATURE RESERVE, -34.8550°S 117.8470°E, JUDD, S., 18-12-98, L90; C30205, MILLBROOK NATURE RESERVE, -34 8550°S 117.8470°E, JUDD, S , 18-12-98, G40, C30206, DUNSBOROUGH CNR. COMMONAGE/WILDWOOD RDS, -33.6920°S 115.0670°E, JUDD, S., 15-07-98, G20, C30207/8, DUNSBOROUGH CNR COMMONAGE/WILDWOOD RDS, -33 6920°S 115.0670°E, JUDD, S , 15-07-98, L10; C30209/10, SCARP ROAD NEAR NORTH DANDALUP, -32 5600°S 116.0050°E, JUDD, S , 29-07-98, L10, C30211/12, SCARP ROAD NEAR NORTH DANDALUP, -32 5600°S 116.0050°E, JUDD, S , 29-07-98, L20; C30213, WELLINGTON MILL, -33.4430°S 115.9080°E, JUDD, S., 30-07-98, S1, C30214, MT. LENNARD COLLIE RIVER, -33.3620°S 115.9030°E, JUDD, S., 30-07-98, L10; C30215, MT. LENNARD COLLIE RIVER, -33.3620°S 115.9030°E, JUDD, S., 30-07-98, G20; C30216/8, NAMMING NATURE RESERVE?, -30.8560°S 115.5880°E, JUDD, S , 06-08-98, L10; C30219, NILGEN NATURE RESERVE TUKEY TRACK, -30.8730°S 115 3070°E, JUDD, S , 07-08-98, B40; C30220, JOHN FOREST NATIONAL PARK JANE BROOK, -31.8850°S 116 0900°E, JUDD, S., 11-08-98, R1; C30221, JOHN FOREST NATIONAL PARK (SCARP), -31 8900°S 116 0870°E, JUDD, S., 11-08-98, L30, C30222, JOHN FOREST NATIONAL PARK (SCARP), -31 8900°S 116 0870°E, JUDD, S., 11-08-98, L10; C30223/4, D'ENTRECASTEAUX NATIONAL PARK, QUINERUP SPRING, -34 4420°S 115 6850°E, JUDD, S., 14-08-98, G50; C30225, D'ENTRECASTEAUX NATIONAL PARK, QUINERUP SPRING, -34.4420°S 115 6850°E, JUDD, S., 14-08-98, L40; C30226, D'ENTRECASTEAUX NATIONAL PARK, QUINERUP SPRING, -34 4420°S 115 6850°E, JUDD, S., 14-08-98, G40; C30227, CLEAVE ROAD OFF SCOTT RD, -34 4180°S 115.7930°E, JUDD, S., 14-08-98, E1; C30228, CLEAVE ROAD OFF SCOTT RD, -34 4180°S 115.7930°E, JUDD, S., 14-08-98, L50; C30229, CLEAVE ROAD OFF SCOTT RD, -34.4180°S 115 7930°E, JUDD, S., 14-08-98, G30, C30230, CLEAVE ROAD OFF SCOTT RD, -34.4180°S 115.7930°E, JUDD, S , 14-08-98, L20; C30231, CLEAVE ROAD OFF SCOTT RD, -34 4180°S 115 7930°E, JUDD, S., 14-08-58, G40; C30232, BIG BROOK DAM FOREST, -34.4050°S 116 0270°E, JUDD, S , 15-08-98, L10, C30233, BIG BROOK DAM FOREST, -34.4050°S 116.0270°E, JUDD, S., 15-08-98, L20; C30234/5, YORNUP BLOCK UPPER DONNELLY RIVER, -34.0980°S 116.1580°E, JUDD, S., 15-08-98, L10, C30236, YEAL SWAMP, -31.4700°S 115.7620°E, JUDD, S., 01-10-98, L60; C30237, YEAL SWAMP, -31.4700°S 115.7620°E, JUDD, S., 01-10-98, R5; C30238/9, YEAL SWAMP, -31.4700°S 115.7620°E, JUDD, S., 01-10-98, L20; C30240/2, PINJAR POWER STATION, -31.5560°S 115 8600°E, JUDD, S., 06-10-98, L10; C30243/4, BOONANARING NATURE RESERVE, -31.2100°S 115.9030°E, JUDD, S., 07-10-98, G30; C30245, BOONANARING NATURE RESERVE, -31.2500°S 115 9100°E, JUDD, S., 07-10-98, G10, C30246, BOONANARING NATURE RESERVE, -31.2500°S 115.9100°E, JUDD, S., 07-10-98, L10; C30247, BOONANARING NATURE RESERVE, -31 2500°S 115.9100°E, JUDD, S., 07-10-98, G30; C30248/9, JULIMAR CONSERVATION PARK, -31.3950°S 116.2950°E, JUDD, S , 09-10-98, G30; C30250, ST. RONANS NATURE RESERVE, -31 8730°S 116 6400°E, JUDD, S , 21-10-98, L10; C30251/2, MONADNOCKS CONSERVATION PARK MARGINATA ROAD, -32 2420°S 116.2050°E, JUDD, S., 04-11-98, L20; C30253, WHITE HORSE HILL, -32 6070°S 116.2950°E, JUDD, S., 06-11-98, L10; C30254, YALGORUP NATIONAL PARK, -32 9130°S 115.6830°E, JUDD, S , 13-11-98, L40; C30255, NOGGERUP CONSERVATION PARK, -33 6220°S 116.1230°E, JUDD, S , 24-11-98, L20; C30256, PRESTON CONSERVATION PARK, -33 6030°S 116 0630°E, JUDD, S., 24-11-98, L20; C30257, PRESTON CONSERVATION PARK, -33.6030°S 116 0630°E, JUDD, S., 24-11-98, L10; C30258, PRESTON CONSERVATION PARK, -33.6030°S 116 0630°E, JUDD, S., 24-11-98, G20; C30259, LUDLOW TUART FOREST, -33 6150°S 115.4670°E, JUDD, S., 25-11-98, G30; C30260/2, LUDLOW TUART FOREST, -33.6150°S 115 4670°E, JUDD, S., 25-11-98, G20, C30263, LUDLOW TUART FOREST, -33 6150°S 115 4670°E, JUDD, S., 25-11-98, G30; C30264/5, BENGER SWAMP NATURE RESERVE, -33.1780°S 115 8330°E, JUDD, S , 25-11-98, L10; C30266, BENGER SWAMP NATURE RESERVE, -33.1780°S 115 8330°E, JUDD, S., 25-11-98, B40; C30267, BRIDGETOWN WEST NATURE RESERVE, -33.9520°S 116 0780°E, JUDD, S , 01-12-98, L10; C30268, BRIDGETOWN JARRAH PARK, -34 0300°S 115 9830°E, JUDD, S , 01-12-98, L20; C30269, BRIDGETOWN JARRAH PARK, -34.0300°S 115 9830°E, JUDD, S., 01-12-98, L40, C30270, BRIDGETOWN JARRAH PARK, -34.0300°S 115 9830°E, JUDD, S , 01-12-98, L10; C30271, ST JOHNS CONSERVATION PARK, -33.9450°S 115.6900°E, JUDD, S.,

02-12-98, L10; C30272, ELLIS CREEK ROAD, -33 9350°S 115 8820°E, JUDD, S , 03-12-98, G30; C30273, BURNSIDE ROAD NATURE RESERVE, -32 7230°S 115 9430°E, JUDD, S , 03-12-98, L10, C30274, LEEUWIN NATURALISTE NATIONAL PARK (QUININUP KARRI), -33.7350°S 115.0070°E, JUDD, S., 07-12-98, L10, C30275, LEEUWIN NATURALISTE NATIONAL PARK (QUININUP KARRI), -33 7350°S 115 0070°E, JUDD, S., 07-12-98, G20; C30276, GINGILUP SWAMPS NATURE RESERVE, -34 3320°S 115.4400°E, JUDD, S., 09-12-98, L10, C30277/8, PORONGORUP NATIONAL PARK BOLGANUP DAM, -34 6700°S 117 8820°E, JUDD, S , 16-12-98, L41; C30279, MILLBROOK NATURE RESERVE, -34 8550°S 117.8470°E, JUDD, S., 18-12-98, L90, C30280, MILLBROOK NATURE RESERVE, -34.8550°S 117.8470°E, JUDD, S , 18-12-98, G40, C30281, DOWN ROAD NATURE RESERVE, -34 9550°S 117 7580°E, JUDD, S , 20-12-98, L20; C30282, DOWN ROAD NATURE RESERVE, -34.9550°S 117.7580°E, JUDD, S., 20-12-98, L10, C30283, PARDELUP NATURE RESERVE, -34 6720°S 117 4150°E, JUDD, S , 20-12-98, G20; C30284/6, PARDELUP NATURE RESERVE, -34.6720°S 117 4150°E, JUDD, S., 20-12-98, L10; C30287, PARDELUP NATURE RESERVE, -34.6720°S 117 4150°E, JUDD, S., 20-12-98, B30, C30288, RATE BLOCK, -34 8350°S 117.0070°E, JUDD, S., 09-01-99, L10, C30289, RATE BLOCK, -34.8350°S 117 0070°E, JUDD, S , 09-01-99, L41; C30290, ORDNANCE STATE FOREST, -34.8680°S 116 6650°E, JUDD, S., 10-01-99, L10, C30291, ORDNANCE STATE FOREST, -34 8680°S 116 6650°E, JUDD, S , 10-01-99, G20; C30292, ORDNANCE STATE FOREST, -34.8680°S 116 6650°E, JUDD, S., 10-01-99, L10, C30293, MOUNT FRANKLAND NATIONAL PARK CROSSING BLOCK, -34.8030°S 116.8830°E, JUDD, S., 10-01-99, L10; C30294, MOUNT FRANKLAND NATIONAL PARK CROSSING BLOCK, -34.8030°S 116 8830°E, JUDD, S , 10-01-99, L10; C30295/6, WALPOLE NORNALUP NATIONAL PARK, -34 9880°S 116.7600°E, JUDD, S., 11-01-99, L10, C30297/8, WALPOLE NORNALUP NATIONAL PARK, -34 9880°S 116.7600°E, JUDD, S., 11-01-99, L20, C30299/301, LONG/THOMPSON BLOCK, -34.6600°S 116.7030°E, JUDD, S., 11-01-99, L10, C30302, DE LANDGRAFFT ROAD, -34 2670°S 116 5920°E, JUDD, S., 26-01-99, G20; C30303, DE LANDGRAFFT ROAD, -34.2670°S 116.5920°E, JUDD, S., 26-01-99, L10; C30304, SHANNON NATIONAL PARK (FISH CREEK ROAD), -34.6250°S 116 4370°E, JUDD, S., 27-01-99, L10; C30305, SHANNON NATIONAL PARK (FISH CREEK ROAD), -34 6250°S 116.4370°E, JUDD, S., 27-01-99, L20, C30306, SHANNON NATIONAL PARK (FISH CREEK ROAD), -34.6250°S 116 4370°E, JUDD, S , 27-01-99, G20; C30307, SHANNON NATIONAL PARK (FISH CREEK ROAD), -34 6250°S 116.4370°E, JUDD, S., 27-01-99, L10; C30308, MT CHUDALUP, -34.7630°S 116.0830°E, JUDD, S., 28-01-99, L10; C30309, MT. CHUDALUP, -34.7630°S 116 0830°E, JUDD, S., 28-01-99, G20; C30310, MT. CHUDALUP, -34 7630°S 116 0830°E, JUDD, S., 28-01-99, L30; C30311, MT CHUDALUP, -34.7630°S 116.0830°E, JUDD, S., 28-01-99, L10, C31289, MT COOKE, -32 4167°S 116 3000°E, HARVEY, M. S. & WALDOCK, J. M., 15-05-91, P3, C31290, TAMBELUP, -34.0333°S 117 6333°E, GORDON, P., 15-09-28; C31291, ARMADALE, -32 1500°S 116 0000°E, BOWLEY, E. A., 28-06-32, C31292, SOUTH PERTH, -31.9833°S 115 8667°E, COLLECTOR UNKNOWN, 14-06-32; C31293, WOOROLOO NEAR CREEK IN SWINBURN'S PADDOCK, NORTHAM RD, -31 8000°S 116.3000°E, NICHOLLS COLLECTION, ??-08-32; C31294, WOOROLOO NEAR HOUSE, -31 8000°S 116.3000°E, NICHOLLS COLLECTION, ??-08-32; C31295, WALPOLE INLET CAMP SITE, -34.9833°S 116 7333°E, NICHOLLS COLLECTION, 01-01-33; C31296/9, GLENBOURNE FARM OLD ELLENSBROOK ROAD NEAR MARGARET RIVER, -33.9167°S 115.0167°E, MARSH, L. ET AL., 30-06-97, P2, C31300/4, GLENBOURNE FARM OLD ELLENSBROOK ROAD NEAR MARGARET RIVER, -33 9167°S 115.0167°E, MARSH, L. ET AL., 15-09-97, P2; C31305/6, GLENBOURNE FARM OLD ELLENSBROOK ROAD NEAR MARGARET RIVER, -33.9167°S 115 0167°E, MARSH, L. ET AL., 29-12-97, P2; C31307, WALPOLE NORNALUP NATIONAL PARK, -34.9833°S 116 7167°E, WALLIS, N., ??-??-91; C31308, PORONGURUP NATIONAL PARK S END OF MILLINUP PASS, -34 6953°S 117.8975°E, HARVEY, M S., 02-09-96, P3; C31309, MT LESUEUR 3 5 KM NE, -30.1500°S 115 2333°E, UWA 32, 11-07-89; C31310, MT LESUEUR 3 KM NEE, -30.1333°S 115 2000°E, UWA 33, 09-07-89, R4; C31311, MT LESUEUR 5.5 KM NNE, -30.1333°S 115 2000°E, UWA 36, 10-07-89, R1, C31312, MT LESUEUR 2 5 KM NE, -30 1667°S 115 2000°E, UWA 13 JASON, 11-07-89, R1; C31313, MT PERON 4.5 KM E, -30 1000°S 115 2000°E, UWA 34, 12-07-89, L50; C31314, STIRLING RANGE NATIONAL PARK BLUFF KNOLL THE CASCADES, -34 3747°S 118.2381°E, HARVEY, M. S. ET AL , 04-09-96, P3; C31315, GLENBOURNE FARM OLD ELLENSBROOK ROAD NEAR MARGARET RIVER, -33 9167°S 115 0167°E, MARSH, L. ET AL , 20-05-98, P2; C31316/7, WALPOLE NORNALUP NATIONAL PARK JARRAH FOREST, -34 9917°S 116 7083°E, VAN HEURCK, P. ET AL , 13-05-97, L10; C31318, WALPOLE NORNALUP NATIONAL PARK KARRI FOREST, -34.9833°S 116 7083°E, VAN HEURCK, P. ET AL., 13-05-97, L40, C31319, WALPOLE NORNALUP NATIONAL PARK KARRI FOREST, -35 0000°S 116 7167°E, VAN HEURCK, P. ET AL , 13-05-97, L40; C31320, WALPOLE NORNALUP NATIONAL PARK TINGLE UPLAND FOREST, -34 9917°S 116 6500°E, VAN HEURCK, P. ET AL., 20-05-97, L10, C31321, WALPOLE NORNALUP NATIONAL PARK TINGLE CREEK FOREST, -34 9917°S 116 6583°E, VAN HEURCK, P. ET AL , 20-05-97, L40; C31322, WALPOLE NORNALUP NATIONAL PARK TINGLE UPLAND FOREST, -34 9583°S 116.7750°E, VAN HEURCK, P ET AL , 16-05-97, L10, C31323, WALPOLE NORNALUP NATIONAL PARK TINGLE CREEK FOREST, -34 9750°S 116.7917°E, VAN HEURCK, P. ET AL., 14-05-97, L40; C31324, WALPOLE NORNALUP NATIONAL PARK TINGLE CREEK FOREST, -34 9750°S 116.7833°E, VAN HEURCK, P. ET AL., 16-05-97, L10; C31325, CAPE LEEUWIN SWAMP SOUTHEAST CORNER OF WATER AUTHORITY COMPOUND, -34 3667°S 115 1333°E, SLACK-SMITH, S. ET AL , 19-08-00, S1; C31326, CAPE LEEUWIN SWAMP SOUTHERN FENCE OF WAWA COMPOUND, -34.3667°S 115 1333°E, SLACK-SMITH, S. ET AL., 20-08-00, L10; C31327, CAPE LEEUWIN SWAMP NEAR SOUTHERN FENCE OF WAWA COMPOUND, -34 3667°S 115 1333°E, SLACK-SMITH, S. ET AL , 20-08-00, S1; C31328/30, GLENBOURNE FARM OLD ELLENSBROOK ROAD NEAR MARGARET RIVER, -33 9167°S 115.0167°E, MARSH, L. ET AL., 26-10-98, P2; C31331/5, GLENBOURNE FARM OLD ELLENSBROOK ROAD NEAR MARGARET RIVER, -33 9167°S 115 0167°E, MARSH, L. ET AL , 01-11-99, P2, C31336, COOROW GREEN HEAD ROAD, -30.0636°S 115.1794°E, WALDOCK, J. M., 30-09-00, L10, C31868, WARWICK OPEN SPACE, -31.8428°S 115.8139°E, HARVEY, M S. & WALDOCK, J M., 28-11-95, P3; C31869, WARWICK OPEN SPACE, -31 8425°S 115 8167°E, HARVEY, M. S & WALDOCK, J M , 25-09-95, P3, C31870, WARWICK OPEN SPACE, -31.8428°S 115 6139°E, HARVEY, M S. & WALDOCK, J. M., 25-09-95, P3; C31871, WARWICK OPEN SPACE, -31 8425°S 115 8167°E, HARVEY, M S & WALDOCK, J. M , 28-11-95, P3; C31872, WARWICK OPEN SPACE, -31 8428°S 115 8139°E, HARVEY, M S & WALDOCK, J. M , 29-01-96, P3, C31873, LANDSDALE SCHOOL, -31.8206°S 115 8503°E, WALDOCK, J. M., WEST, P. L. & WHEELER, A., 28-03-96, P3; C31874, LANDSDALE SCHOOL, -31.8206°S 115 8503°E, HARVEY, M S & WALDOCK, J M , 25-09-95,

P3; C31875, WOODMAN POINT, -32.1297°S 115.7564°E, HARVEY, M. S & WALDOCK, J M., 06-07-95, P3; C31876, TUART HILL, -31.8806°S 115 8589°E, WALDOCK, J. M., SAMPEY, A. & THORPE, A., 23-09-93, P3; C31877, TUART HILL, -31.8803°S 115.8583°E, WALDOCK, J. M. ET AL., 18-11-93, P3; C31878, MARANGAROO RESERVE, -31.8308°S 115.8342°E, HARVEY, M. S. & WALDOCK, J. M., 25-09-95, P3; C31879, MARANGAROO RESERVE, -31.8308°S 115.8342°E, WALDOCK, J M, WEST, P. L. & WHEELER, A, 28-03-96, P3; C31880, MARANGAROO RESERVE, -31.8272°S 115.8344°E, HARVEY, M. S & WALDOCK, J M., 25-09-95, P3; C31881, MARANGAROO RESERVE, -31 8308°S 115 8342°E, DELL, J, 19-11-95, P2, C31882, MT HENRY, -32.0314°S 115.8622°E, HARVEY, M. S & WALDOCK, J. M., 06-07-95, P3; C31883, MT HENRY, -32.0314°S 115 8622°E, HARVEY, M. S. & WALDOCK, J. M., 04-05-95, P3, C31884, TRIGG DUNE RUSH, -31.8792°S 115.7547°E, HARVEY, M. S. & WALDOCK, J. M., 29-01-96, P3, C31885, BOLD PARK, -31.9372°S 115.7711°E, HARVEY, M S. & WALDOCK, J M., 20-07-93, P3; C31886, BOLD PARK, -31.9417°S 115 7742°E, HOW, R., 24-12-93, P2, C31887, BOLD PARK, -31.9364°S 115 7639°E, WALDOCK, J. M. ET AL., 24-09-93, P3, C31888, BOLD PARK, -31 9353°S 115 7750°E, HARVEY, M. S. & WALDOCK, J. M., 20-07-93, P3; C31889, BOLD PARK, -31.9417°S 115.7742°E, WALDOCK, J M. ET AL., 18-11-93, P3; C31890, BOLD PARK, -31 9372°S 115.7711°E, WALDOCK, J M., 24-09-93, P3; C31891, BOLD PARK, -31 9364°S 115 7839°E, HARVEY, M S. & WALDOCK, J. M., 19-05-94, P3; C31892, BOLD PARK, -31.9425°S 115 7703°E, HARVEY, M. S. & WALDOCK, J. M., 20-07-93, P3; C31893, BOLD PARK, -31.9417°S 115.7742°E, WALDOCK, J M., 06-01-94, P3; C31894, BOLD PARK, -31 9372°S 115.7711°E, WALDOCK, J. M. ET AL., 19-11-93, P3, C31895, BOLD PARK, -31 9364°S 115 7639°E, WALDOCK, J. M. ET AL., 18-11-93, P3; C31896, BOLD PARK, -31 9414°S 115 7669°E, WALDOCK, J. M, GOODSELL, J. & WEBB, J., 06-01-94, P3, C31897, BOLD PARK, -31 9372°S 115 7711°E, WALDOCK, J M., 06-01-94, P3; C31898, BOLD PARK, -31.9364°S 115 7639°E, WALDOCK, J. M, 06-01-94, P3; C31899, BRICKWOOD RESERVE, CARDUP, -32.2333°S 116.0006°E, WALDOCK, J M., WEST, P. L. & LONGBOTTOM, A, 17-06-96, P3; C31900, RUSHTON ROAD, -32.0639°S 116.0189°E, WALDOCK, J. M., WEST, P. L. & LONGBOTTOM, A., 17-06-96, P3; C31901, RUSHTON ROAD, -32 0639°S 116 0189°E, WALDOCK, J. M., WEST, P. L. & LONGBOTTOM, A, 17-06-96, P3; C31902, JANDAKOT AIRPORT, -32.0919°S 115 8744°E, WALDOCK, J M & HARVEY, M S., 19-01-95, P3; C31903, JANDAKOT AIRPORT, -32.0919°S 115.8744°E, WALDOCK, J. M. & LONGBOTTOM, A. F., 01-09-94, P3; C31904, JANDAKOT AIRPORT, -32.0919°S 115 8744°E, WALDOCK, J. M. & LONGBOTTOM, A. F., 04-11-94, P3; C31905, JANDAKOT AIRPORT, -32.0933°S 115.8775°E, WALDOCK, J. M. & HARVEY, M. S., 19-01-95, P3; C31906, JANDAKOT AIRPORT, -32.0933°S 115 8775°E, WALDOCK, J. M. & LONGBOTTOM, A F., 04-11-94, P3; C31907, JANDAKOT AIRPORT, -32 0933°S 115 8775°E, DELL, J., 11-12-94, P2; C31908, JANDAKOT AIRPORT, -32.0933°S 115 8775°E, WALDOCK, J. M. & LONGBOTTOM, A. F., 01-09-94, P3; C31909, HEPBURN HEIGHTS, -31 8172°S 115 7703°E, WALDOCK, J. M. & HARVEY, M. S., 28-11-95, P3; C31910, HEPBURN HEIGHTS, -31.8188°S 115 7697°E, WALDOCK, J. M. & HARVEY, M. S., 25-09-95, P3; C31911, HEPBURN HEIGHTS, -31.8188°S 115.7697°E, WALDOCK, J. M. & HARVEY, M S., 25-09-95, P3; C31912, HEPBURN HEIGHTS, -31.8186°S 115.7697°E, WALDOCK, J. M. & HARVEY, M. S., 29-01-96, P3; C31913, HEPBURN HEIGHTS, -31.8158°S 115 7781°E, WALDOCK, J. M. & HARVEY, M. S., 28-11-95, P3, C31914, HEPBURN HEIGHTS, -31.8183°S 115 7672°E, WALDOCK, J. M & HARVEY, M S, 29-01-96, P3; C31915, HEPBURN HEIGHTS, -31.8183°S 115 7672°E, WALDOCK, J M & HARVEY, M S, 28-11-95, P3; C31916, HEPBURN HEIGHTS, -31.8183°S 115.7672°E, WALDOCK, J. M & HARVEY, M S., 25-09-95, P3, C31917, NORMAN ROAD, CARDUP, -32.2636°S 116.0036°E, WALDOCK, J M, WEST, P. L. & LONGBOTTOM, A., 17-06-96, P3; C31918, MT CLAREMONT, -31 9611°S 115.7667°E, WALDOCK, J M & HARVEY, M S, 19-01-95, P3; C31919, MT CLAREMONT, -31 9611°S 115.7867°E, WALDOCK, J. M. & LONGBOTTOM, A. F., 04-11-94, P3, C31920, MT CLAREMONT, -31 9608°S 115.7656°E, WALDOCK, J. M. & LONGBOTTOM, A F., 04-11-94, P3; C31921, MT CLAREMONT, -31 9608°S 115 7656°E, WALDOCK, J. M. & LONGBOTTOM, A. F., 06-07-95, P3; C31922, MT CLAREMONT, -31.9608°S 115 7656°E, WALDOCK, J M & HARVEY, M S., 19-01-95, P3; C31923, TALBOT ROAD RESERVE, -31.8733°S 116 0478°E, DELL, J., 29-08-93, P2; C31924, BOLD PARK, -31.9414°S 115 7669°E, WALDOCK, J. M., 24-09-93, P3; C31925, BOLD PARK, -31 9414°S 115.7669°E, WALDOCK, J. M, 24-09-93, P3, C31926, PERTH AIRPORT, -31.9761°S 115 9738°E, WALDOCK, J. M. ET AL, 23-09-93, P3; C31927, PERTH AIRPORT, -31.9681°S 115.9681°E, WALDOCK, J M. ET AL., 23-09-93, P3; C31928, PERTH AIRPORT, -31 9675°S 115 9697°E, WALDOCK, J. M. ET AL., 18-11-93, P3.

Diagnosis: Runner/creeper. Animal of medium/large size (~8 mm) with strong colouring and of terrestrial origin. Animal long and thin with a base colouring of brown with cream markings. Pereonal epimera brown coloured with cream patches on each pereonite parallel to the outer lateral border of each epimeron. Pleopod exopodites of female rounded and usually of a single colour. Pleopod exopodites 1 and 2 pointed on inner border.

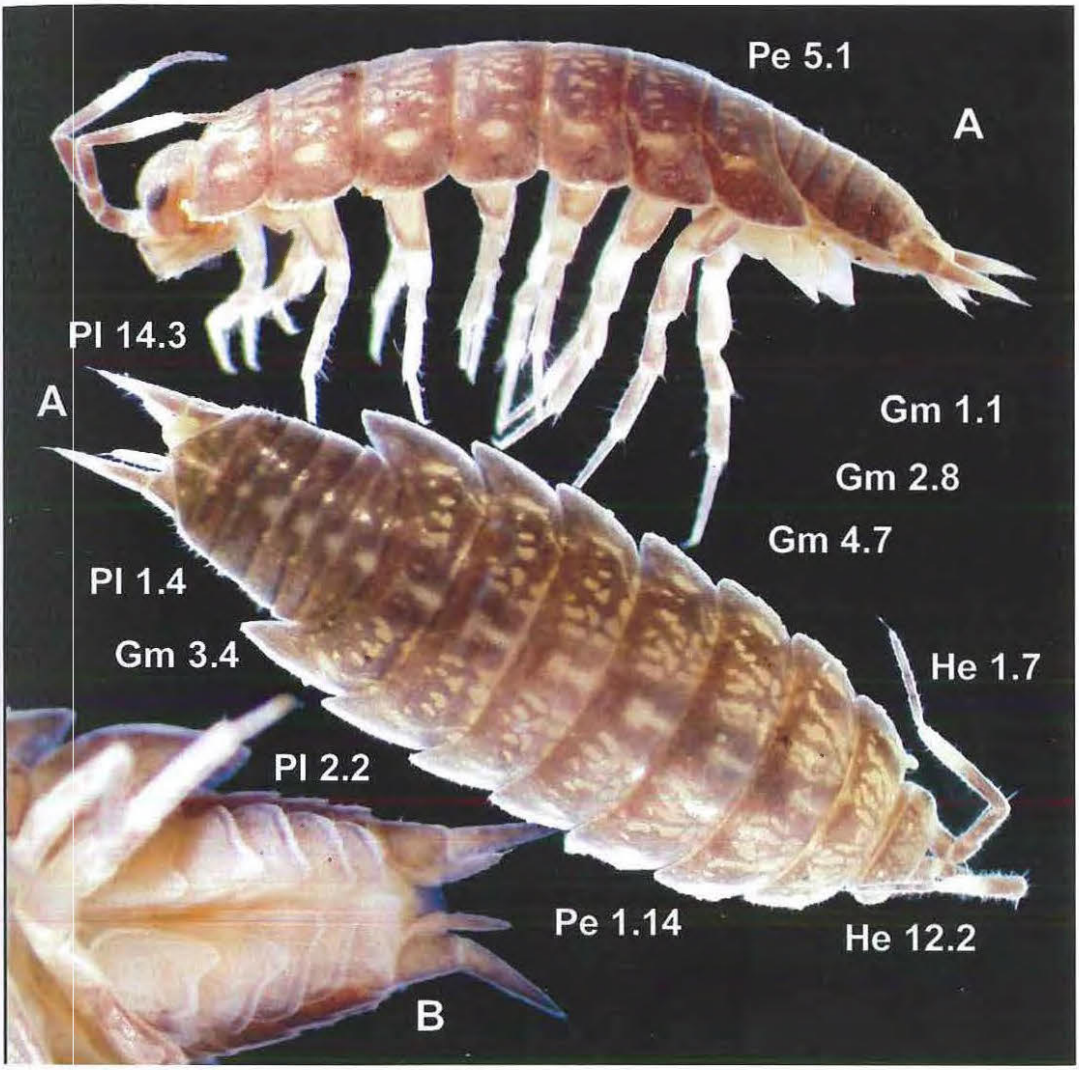


Plate 3.70. Laevophiloscia sp 1 from (A) jarrah forest at Scarp Road near North Dandalup (C30210) (length 8 mm) and (B) Wannamal Lakes Nature Reserve (C30151) (length 8 mm).

3.16.4.2. Laevophiloscia species 2

Plate 3.2, Gm 2.9; Plate 3.4, Gm 4.8; Plate 3.16, He 12.2; Plate 3.23, Pe 7.1; Plate 3.35, Pl 2.3; Plate 3.71.

Philoscia (Laevophiloscia) perlata Wahrberg, 1922

Laevophiloscia perlata Bowley, 1935

Laevophiloscia perlata Vandel, 1973

Laevophiloscia perlata Bunn & Green, 1982

Laevophiloscia sp. 2 Judd & Horwitz, 2003

MATERIAL EXAMINED: C789/90, DARLINGTON, -31.9167°S 116.0667°E, GLAUERT, L., 23-10-22, L10; C2092/96, ROTTNEST ISLAND LONGREACH BAY, -32.0000°S 115.5000°E, GLAUERT, L., ??-09-27; C2133/38, ROTTNEST ISLAND MT HERSCHELL (NEAR), -32 0000°S 115.5000°E, GLAUERT, L., ??-??-27; C2149/58, ROTTNEST ISLAND LAKE HERSCHELL NORTH SHORE, -32.0000°S 115 5000°E, GLAUERT, L., ??-??-27; C2180/89, ROTTNEST ISLAND LAKE BAGHDAD, -32 0000°S 115.5000°E, GLAUERT, L., ??-??-27, C2214/19, ROTTNEST ISLAND, POINT CLUNE, -31.9830°S 115 5170°E, GLAUERT, L., ??-??-27; C2256/8, ROTTNEST ISLAND NORTH POINT, -32 0000°S 115.5100°E, GLAUERT, L , ??-??-27; C10829, NORTH BEACH, -31.8667°S 115.7500°E, NICHOLLS COLLECTION, 29-07-33; C12895, ROTTNEST ISLAND LIGHTHOUSE SWAMP, -32 0000°S 115.5000°E, BUNN, S., 07-05-80, C12896, ROTTNEST ISLAND ISLET 18, -32 0000°S 115.5000°E, BUNN, S., 06-05-80, C12897, ROTTNEST ISLAND ISLET 20, -32.0000°S 115.5000°E, BUNN, S., 06-05-80; C12898, ROTTNEST ISLAND ISLET 38, -32.0000°S 115.5000°E, BUNN, S., 07-05-80; C30312/14, DUNSBOROUGH CNR COMMONAGE/WILDWOOD RDS, -33.6920°S 115.0670°E, JUDD, S., 15-07-98, L10; C30315, LEONA ROAD, -32.2160°S 116 3250°E, JUDD, S., 23-07-98, L10; C30316, GINGAGUP BROOK SCARP, -32.3150°S 116.0350°E, JUDD, S., 29-07-96, L10; C30317/19, KARNET BROOK, -32.4070°S 116.0270°E, JUDD, S., 29-07-98, L10, C30320, SCARP ROAD NEAR NORTH DANDALUP, -32.5600°S 116.0050°E, JUDD, S , 29-07-98, L20; C30321, WELLINGTON MILL, -33 4430°S 115.9080°E, JUDD, S., 30-07-98, R1; C30322/3, WELLINGTON MILL, -33.4430°S 115 9080°E, JUDD, S., 30-07-98, L20, C30324/5, MT. LENNARD, -33 3920°S 115.8870°E, JUDD, S., 30-07-98, L10; C30326, MT. LENNARD COLLIE RIVER, -33.3620°S 115.9030°E, JUDD, S., 30-07-98, G30; C30327, WARREN NATIONAL PARK TREAN BROOK, -34.4820°S 115.9250°E, JUDD, S., 13-08-98, L10; C30328, WARREN NATIONAL PARK TREAN BROOK, -34.4820°S 115 9250°E, JUDD, S., 13-08-98, L20; C30329, WARREN NATIONAL PARK TREAN BROOK, -34.4820°S 115 9250°E, JUDD, S., 13-08-98, G20; C30330, WARREN NATIONAL PARK TREAN BROOK, -34.4820°S 115.9250°E, JUDD, S., 13-08-98, L41; C30331, D'ENTRECASTEAUX NATIONAL PARK, QUINERUP SPRING, -34 4420°S 115.6850°E, JUDD, S., 14-08-98, G50; C30332, D'ENTRECASTEAUX NATIONAL PARK, QUINERUP SPRING, -34.4420°S 115.6850°E, JUDD, S., 14-08-98, L40; C30333, D'ENTRECASTEAUX NATIONAL PARK, QUINERUP SPRING, -34 4420°S 115.6850°E, JUDD, S., 14-08-98, G40; C30334, D'ENTRECASTEAUX NATIONAL PARK, QUINERUP SPRING, -34 4420°S 115.6850°E, JUDD, S., 14-08-98, L10; C30335, CLEAVE ROAD OFF SCOTT RD, -34.4180°S 115 7930°E, JUDD, S., 14-08-98, E1; C30336, CLEAVE ROAD OFF SCOTT RD, -34.4180°S 115 7930°E, JUDD, S., 14-08-98, G30; C30337, CLEAVE ROAD OFF SCOTT RD, -34.4180°S 115.7930°E, JUDD, S., 14-08-98, G40; C30338, BIG BROOK DAM FOREST, -34 4050°S 116.0270°E, JUDD, S., 15-08-98, L20, C30339/40, BIG BROOK DAM FOREST, -34.4050°S 116.0270°E, JUDD, S., 15-08-98, L10; C30341, BIG BROOK DAM FOREST, -34.4050°S 116 0270°E, JUDD, S., 15-08-98, L20; C30342, CANNING RIVER (BELOW CANNING DAM), -32.1430°S 116.1100°E, JUDD, S., 25-08-98, L30; C30343, YANCHEP NATIONAL PARK, -31.5200°S 115 6630°E, JUDD, S , 13-10-98, L20, C30344, YANCHEP NATIONAL PARK, -31.5200°S 115 6630°E, JUDD, S , 13-10-98, L10, C30345, YANCHEP NATIONAL PARK, -31.5200°S 115.6630°E, JUDD, S., 13-10-98, R4, C30346/7, YANCHEP NATIONAL PARK, -31.5200°S 115 6630°E, JUDD, S , 13-10-98, L10; C30348/9, MOORE RIVER NORTH BANK, -31 3530°S 115 5020°E, JUDD, S , 18-10-98, R1, C30350, MOORE RIVER NORTH BANK, -31.3530°S 115.5020°E, JUDD, S., 18-10-98, L30; C30351, SCHULSTAAD ROAD CREEK, -32 2800°S 116.3600°E, JUDD, S , 05-11-98, L10; C30352, JINGALUP NATURE RESERVE, -34.0130°S 117.0130°E, JUDD, S , 29-10-98, L60; C30353, NARLINGUP NATURE RESERVE, -33 8630°S 116.8900°E, JUDD, S , 29-10-98, G30; C30354, PROPOSED LANE POOLE EXTENSION, -33 2030°S 116 4630°E, JUDD, S., 30-10-98, G40, C30355, HARRIS DAM, -33.2550°S 116 1150°E, JUDD, S , 30-10-98, L10; C30356/7, MONADNOCKS CONSERVATION PARK MARGINATA ROAD, -32.2420°S 116.2050°E, JUDD, S., 04-11-98, L20, C30358, MONADNOCKS CONSERVATION PARK MARGINATA ROAD, -32.2420°S 116 2050°E, JUDD, S , 04-11-98, L10; C30359, SCHULSTAAD ROAD CREEK, -32 2800°S 116.3600°E, JUDD, S , 05-11-98, G30; C30360, SCHULSTAAD ROAD CREEK, -32 2800°S 118.3600°E, JUDD, S., 05-11-98, L10; C30361, WHITE HORSE HILL, -32 6070°S 116 2950°E, JUDD, S., 06-11-98, L10; C30362, AMPHION FOREST BLOCK, -32.7920°S 116.1870°E, JUDD, S., 10-11-98, L10; C30363, AMPHION FOREST BLOCK, -32.7920°S 118.1870°E, JUDD, S., 10-11-98, L20; C30364/5, AMPHION FOREST BLOCK, -32 7920°S 116 1870°E, JUDD, S , 10-11-98, L10, C30366, LEPERS GULLY ROAD, -32.8470°S 116 1080°E, JUDD, S , 10-11-98, L10, C30367, LEPERS GULLY ROAD, -32 8470°S 118.1080°E, JUDD, S., 10-11-98, L20; C30368, LEPERS GULLY ROAD, -32.8470°S 116.1080°E, JUDD, S , 10-11-98, L10, C30369, MURRAY RIVER (CONSERVATION PARK), -32.9700°S 116 3020°E, JUDD, S , 11-11-98, L60, C30370, MURRAY RIVER (CONSERVATION PARK), -32 9700°S 116.3020°E, JUDD, S., 11-11-98, L30; C30371, AUSTIN BAY NATURE RESRVE, -32 6380°S 115.7720°E, JUDD, S., 12-11-98, E1; C30372, AUSTIN BAY NATURE RESRVE, -32 6380°S 115 7720°E, JUDD, S , 12-11-98, L10; C30373, YALGORUP NATIONAL PARK, -32 9130°S 115 6830°E, JUDD, S , 13-11-98, L60, C30374, YALGORUP NATIONAL PARK, -32 9130°S 115 6830°E, JUDD, S., 13-11-98, L10; C30375, YALGORUP NATIONAL PARK, -32 9130°S 115.6830°E, JUDD, S., 13-11-

98, L40; C30376, YALGORUP NATIONAL PARK, -32.9130°S 115 6830°E, JUDD, S , 13-11-98, R4, C30377, NOGGERUP CONSERVATION PARK, -33 6220°S 116 1230°E, JUDD, S , 24-11-98, L10; C30378, NOGGERUP CONSERVATION PARK, -33.6220°S 116 1230°E, JUDD, S., 24-11-98, L20; C30379, NOGGERUP CONSERVATION PARK, -33 6220°S 116 1230°E, JUDD, S , 24-11-98, L50; C30380, NOGGERUP CONSERVATION PARK, -33 6220°S 116 1230°E, JUDD, S , 24-11-98, L10, C30381, PRESTON CONSERVATION PARK, -33 6030°S 116 0630°E, JUDD, S., 24-11-98, L20; C30382/3, PRESTON CONSERVATION PARK, -33 6030°S 116 0630°E, JUDD, S., 24-11-98, L10, C30384, LUDLOW TUART FOREST, -33.6150°S 115 4670°E, JUDD, S., 25-11-98, L40; C30385, LUDLOW TUART FOREST, -33 6150°S 115 4670°E, JUDD, S., 25-11-98, G30; C30386, LUDLOW TUART FOREST, -33.6150°S 115.4670°E, JUDD, S., 25-11-98, G20; C30387, LESCHENAULT CONSERVATION PARK, -33 2250°S 115.6920°E, JUDD, S., 25-11-98, L10, C30388, LESCHENAULT CONSERVATION PARK, -33.2250°S 115 6920°E, JUDD, S., 25-11-98, L70; C30389, LESCHENAULT CONSERVATION PARK, -33 2250°S 115 6920°E, JUDD, S., 25-11-98, L10; C30390, LESCHENAULT CONSERVATION PARK, -33.2250°S 115 6920°E, JUDD, S , 25-11-98, L90; C30391, LESCHENAULT CONSERVATION PARK, -33 2250°S 115 6920°E, JUDD, S , 25-11-98, G30, C30392/3, BENGER SWAMP NATURE RESERVE, -33 1760°S 115 8330°E, JUDD, S , 25-11-98, L10, C30394, CHALK BROOK (LANE POOLE RESERVE), -33 0670°S 116 2320°E, JUDD, S., 26-11-98, B50, C30395, CHALK BROOK (LANE POOLE RESERVE), -33 0670°S 116 2320°E, JUDD, S , 26-11-98, L10; C30396, CHALK BROOK (LANE POOLE RESERVE), -33.0670°S 116 2320°E, JUDD, S., 26-11-98, L50; C30397, CHALK BROOK (LANE POOLE RESERVE), -33.0670°S 116 2320°E, JUDD, S., 26-11-98, G30, C30398, HARVEY RIVER BRIDGE AT QUINDANNING ROAD, -33.0830°S 115 9830°E, JUDD, S., 26-11-98, L10; C30399/400, JOES ROAD, -33 7300°S 115.7530°E, JUDD, S., 30-11-98, L10; C30401, JOES ROAD, -33.7300°S 115 7530°E, JUDD, S , 30-11-98, G30, C30402, CLAYMORE ROAD (HAPPY VALLEY), -33.7020°S 115.6030°E, JUDD, S , 30-11-96, L10; C30403/4, BRIDGETOWN WEST NATURE RESERVE, -33.9520°S 116.0760°E, JUDD, S., 01-12-98, L10; C30405/7, MILYEANNUP CONSERVATION PARK?, -34.0900°S 115 5670°E, JUDD, S., 02-12-98, L10; C30408/9, ELLIS CREEK ROAD, -33.9350°S 115.8820°E, JUDD, S., 03-12-96, L10; C30410, ELLIS CREEK ROAD, -33.9350°S 115 8820°E, JUDD, S., 03-12-98, G40; C30411, ELLIS CREEK ROAD, -33 9350°S 115 8820°E, JUDD, S., 03-12-98, L20; C30412, YELVERTON STATE FOREST, -33 7380°S 115.1020°E, JUDD, S., 07-12-98, G30, C30413/4, YELVERTON STATE FOREST, -33 7380°S 115.1020°E, JUDD, S , 07-12-98, L10, C30415, LEEUWIN NATURALISTE NATIONAL PARK (QUININUP KARRI), -33.7350°S 115 0070°E, JUDD, S., 07-12-98, L10; C30416, LEEUWIN NATURALISTE NATIONAL PARK (QUININUP KARRI), -33 7350°S 115 0070°E, JUDD, S , 07-12-98, B10, C30417/8, RAPIDS CONSERVATION PARK, -33 8770°S 115 2880°E, JUDD, S., 08-12-98, L10; C30419, SPEARWOOD CREEK, -34.0920°S 115 3130°E, JUDD, S., 08-12-98, L10; C30420, SPEARWOOD CREEK, -34.0920°S 115 3130°E, JUDD, S., 08-12-98, L20; C30421, SPEARWOOD CREEK, -34.0920°S 115.3130°E, JUDD, S., 08-12-98, G20; C30422, GINGILUP SWAMPS NATURE RESERVE, -34 3320°S 115.4400°E, JUDD, S., 09-12-98, L10, C30423, GINGILUP SWAMPS NATURE RESERVE, -34 3320°S 115.4400°E, JUDD, S., 09-12-98, L20, C30424, GINGILUP SWAMPS NATURE RESERVE, -34.3320°S 115.4400°E, JUDD, S., 09-12-98, L10, C30425/6, LEEUWIN NATURALISTE NATIONAL PARK HAMELIN BAY, -34 2070°S 115 0380°E, JUDD, S , 10-12-98, L10; C30427/8, LEEUWIN NATURALISTE NATIONAL PARK HAMELIN BAY, -34.2070°S 115.0380°E, JUDD, S., 10-12-96, S1; C30429/30, MARGARET RIVER CREEK, -33 9350°S 115.0650°E, JUDD, S., 10-12-98, L10; C30431, PORONGORUP NATIONAL PARK BOLGANUP DAM, -34.6700°S 117 8820°E, JUDD, S., 16-12-98, L10; C30432, MARBELUP NATURE RESERVE, -34 9920°S 117.7220°E, JUDD, S , 17-12-98, L10; C30433, MARBELUP NATURE RESERVE, -34.9920°S 117 7220°E, JUDD, S., 17-12-98, G30; C30434, MILLBROOK NATURE RESERVE, -34.8550°S 117.8470°E, JUDD, S., 18-12-98, L10; C30435/6, TORNDIRRUP NATIONAL PARK, -35 1150°S 117.9330°E, JUDD, S., 18-12-98, L10; C30437, WAYCHINICUP NATIONAL PARK, -34 8800°S 118.3270°E, JUDD, S , 19-12-98, L30; C30438, WAYCHINICUP NATIONAL PARK, -34.8800°S 118.3270°E, JUDD, S , 19-12-98, L10; C30439, TWO PEOPLES BAY NATURE RESERVE, -34 9770°S 118.1820°E, JUDD, S., 19-12-98, L10; C30440, TWO PEOPLES BAY NATURE RESERVE, -34 9770°S 118.1820°E, JUDD, S , 19-12-98, G20, C30441, TWO PEOPLES BAY NATURE RESERVE, -34.9770°S 118 1820°E, JUDD, S., 19-12-98, L10, C30442, WILLIAM BAY NATIONAL PARK, -35 0020°S 117.2280°E, JUDD, S., 07-01-99, L10, C30443, DENBARKER BLOCK (STAN ROAD), -34.8250°S 117.3470°E, JUDD, S., 08-01-99, L30; C30444, MT LINDESAY (WEST SIDE), -34 8630°S 117 3160°E, JUDD, S., 06-01-99, L20; C30445, MT LINDESAY (WEST SIDE), -34.8630°S 117.3180°E, JUDD, S., 08-01-99, G20; C30446, RATE BLOCK, -34.8350°S 117 0070°E, JUDD, S., 09-01-99, L10, C30447, RATE BLOCK, -34 8350°S 117.0070°E, JUDD, S., 09-01-99, G30; C30448, RATE BLOCK, -34 8350°S 117.0070°E, JUDD, S., 09-01-99, L10, C30449, WILLMOTT BLOCK, -34.6520°S 116.9600°E, JUDD, S., 01-09-99, L10; C30450, CLEAR HILLS/WATERSHED ROAD, -34.6980°S 117.1820°E, JUDD, S., 01-09-99, L10; C30451/2, ORDNANCE STATE FOREST, -34.8680°S 116.8650°E, JUDD, S., 01-01-99, L10, C30453/4, MOUNT FRANKLAND NATIONAL PARK CROSSING BLOCK, -34 8030°S 116.8830°E, JUDD, S., 10-01-99, L10; C30455, WALPOLE NORNALUP NATIONAL PARK SAPPER'S BRIDGE, -34.9600°S 116.8220°E, JUDD, S., 10-01-99, L10; C30456/7, WALPOLE NORNALUP NATIONAL PARK, -34.9880°S 116.7600°E, JUDD, S., 11-01-99, L20; C30458/9, LONG/THOMPSON BLOCK, -34.6600°S 116 7030°E, JUDD, S., 11-01-99, L10; C30460, WARRUP BLOCK, -34.1480°S 116.3320°E, JUDD, S., 25-01-99, L10; C30461, WARRUP BLOCK, -34 1480°S 116.3320°E, JUDD, S., 25-01-99, L20; C30462/3, PERUP NATURE RESERVE, -34.1530°S 116.6070°E, JUDD, S , 25-01-99, L10, C30464, PERUP NATURE RESERVE, -34 1530°S 116 6070°E, JUDD, S., 25-01-99, G30; C30465, DE LANDGRAFFT ROAD, -34 2670°S 116 5920°E, JUDD, S., 26-01-99, G20; C30466, DE LANDGRAFFT ROAD, -34.2670°S 116 5920°E, JUDD, S., 26-01-99, L10; C30467, LAKE UNICUP NATURE RESERVE, -34.3680°S 116.7000°E, JUDD, S , 26-01-99, L10; C30468, SHANNON NATIONAL PARK (FISH CREEK ROAD), -34 6250°S 116.4370°E, JUDD, S., 27-01-99, L10, C30469, SHANNON NATIONAL PARK (FISH CREEK ROAD), -34.6250°S 116 4370°E, JUDD, S., 27-01-99, L20; C30470, SHANNON NATIONAL PARK (FISH CREEK ROAD), -34.6250°S 116 4370°E, JUDD, S , 27-01-99, L10; C30471/2, SHANNON RIVER/CHESAPEAKE RD , -34.8420°S 116.3700°E, JUDD, S., 27-01-99, L10, C30473/4, BOMBAKUP STATE FOREST, -34.6080°S 116.0320°E, JUDD, S., 28-01-99, L10; C30475, MT CHUDALUP, -34.7630°S 116.0830°E, JUDD, S., 28-01-99, L10; C30476, MT. CHUDALUP, -34 7630°S 116 0830°E, JUDD, S., 28-01-99, G20; C30477, MT CHUDALUP, -34 7630°S 116.0830°E, JUDD, S , 28-01-99, L30; C30478, MT. CHUDALUP, -34.7630°S 116 0830°E, JUDD, S., 28-01-99, L41; C30479, MT. CHUDALUP, -34.7630°S 116.0830°E, JUDD, S , 28-01-99, L10; C30480, MOUNT DALE, -32.1259°S

116 2951°E, WATSON, A , 01-10-01, P3; C30481, MOUNT DALE, -32.1259°S 116 2951°E, JUDD, S. & WATSON, A., 26-06-01, G10; C30482/3, MOUNT DALE, -32.1137°S 116 2898°E, WATSON, A., 01-10-01, P3; C30484, MOUNT DALE, -32 0899°S 116 2961°E, WATSON, A., 01-10-01, P3; C30485/6, MOUNT DALE, -32.1071°S 116.2848°E, WATSON, A., 01-10-01, P3, C30487/8, MOUNT DALE, -32.1237°S 116 2934°E, WATSON, A., 01-10-01, P3, C30489, MOUNT DALE, -32.1028°S 116 2961°E, WATSON, A., 01-10-01, P3, C30490, MOUNT DALE, -32 0918°S 116 2779°E, JUDD, S & WATSON, A., 26-06-01, G10; C30491/4, MOUNT DALE, -32.0876°S 116 2784°E, WATSON, A., 01-10-01, P3; C30495, MOUNT DALE, -32.0885°S 116 2810°E, JUDD, S. & WATSON, A , 21-06-01, G10; C30496/7, MOUNT DALE, -32 0992°S 116.2851°E, WATSON, A , 01-10-01, P3; C30498, MOUNT DALE, -32.0869°S 116.2928°E, WATSON, A., 01-10-01, P3; C30499, MOUNT DALE, -32.0869°S 116 2928°E, JUDD, S. & WATSON, A , ??-06-01, G10; C31337, JIMPERDING BROOK, -31 6210°S 116 4170°E, JUDD, S , 20-07-98, G30; C31338, TWO PEOPLES BAY, -34.9833°S 118.1667°E, NICHOLLS COLLECTION, ??-01-38, C31339, PEMBERTON EASTBROOK, -34.4000°S 116.1000°E, BISCOE, M T., 05-01-61; C31340, ARMADALE, -32.1500°S 116.0000°E, COLLECTOR UNKNOWN, 22-06-32; C31341, CANNING RIVER, -32.0333°S 115 8833°E, NICHOLLS COLLECTION, 13-09-25; C31342, COMO, -32.0000°S 115 8667°E, NICHOLLS COLLECTION, 06-06-32; C31343, FLINDERS BAY, -34 3167°S 115 1800°E, NICHOLLS COLLECTION, ??-04-32; C31344, FLINDERS BAY, -34 3167°S 115.1800°E, ARVIDSON, MRS, 07-10-32; C31345, FRANKLAND RIVER, -35 0000°S 116.8167°E, NICHOLLS COLLECTION, 02-12-25, G30; C31346, HARVEY ESTUARY, -32.7667°S 115.7333°E, SERVENTY, D. L., 30-01-28; C31347, HERDSMANS LAKE, -31 9167°S 115.7833°E, COLLECTOR UNKNOWN, 17-05-32, B40; C31348, MILL POINT, -31.9667°S 115 8500°E, COLLECTOR UNKNOWN, 08-08-33; C31349, MUNDARING, -31.9000°S 116 1667°E, COLLECTOR UNKNOWN, ??-??-32; C31350, NEDLANDS, -31 9833°S 115 8000°E, BOWLEY, E. A., 24-06-32; C31351, NORNALUP CAMP, -35.0000°S 116.8167°E, NICHOLLS COLLECTION, ??-11-25; C31352, NORNALUP FRANKLAND RIVER, -35.0000°S 116.8167°E, NICHOLLS COLLECTION, 02-12-25; C31353, NORNALUP, -35.0000°S 116.8167°E, COLLECTOR UNKNOWN, 24-06-32; C31354, PEPPERMINT GROVE BEACH, -32.0000°S 115.7667°E, KEIGHTLEY, R , ??-??-??; C31355, PORONGURUPS, -34.6667°S 117 8333°E, NICHOLLS COLLECTION, ??-12-28; C31356, SWARBRICK'S TRACK VIA ALBANY, -35.0000°S 116.8167°E, NICHOLLS COLLECTION, 04-01-33; C31357, SOUTH PERTH, -31.9833°S 115.8667°E, COLLECTOR UNKNOWN, 12-06-32; C31358, WALPOLE INLET CAMP SITE, -34.9833°S 116.7333°E, NICHOLLS COLLECTION, 12-01-33; C31359, NORNALUP SWARBRICK'S TRACK, -35 0000°S 116.8167°E, COLLECTOR UNKNOWN, 28-01-33; C31360, DARRADUP 3 KM WEST, -34.0833°S 115.5667°E, BANNISTER, J., 14-10-91, L60, C31361, MUNDARING WEIR, -31.9667°S 116 1667°E, WALDOCK, J. M., 06-11-88, L10; C31362, TORBAY HEAD, -35.1333°S 117.6350°E, MAIN, B Y., 17-06-83, P1; C31363, SHANNON NATIONAL PARK DOG POOL ON SHANNON RIVER, -34.7667°S 116.3667°E, HARVEY, M S. & WALDOCK, J. M., 30-04-90, P3, C31364/7, GLENBOURNE FARM OLD ELLENSBROOK ROAD NEAR MARGARET RIVER, -33 9167°S 115.0167°E, MARSH, L. ET AL., 28-10-96, P2, C31368/71, GLENBOURNE FARM OLD ELLENSBROOK ROAD NEAR MARGARET RIVER, -33 9167°S 115 0167°E, MARSH, L ET AL., 31-03-97, P2; C31372/5, GLENBOURNE FARM OLD ELLENSBROOK ROAD NEAR MARGARET RIVER, -33 9167°S 115.0167°E, MARSH, L. ET AL., 30-06-97, P2; C31376/81, GLENBOURNE FARM OLD ELLENSBROOK ROAD NEAR MARGARET RIVER, -33.9167°S 115.0167°E, MARSH, L ET AL., 15-09-97, P2, C31382/85, GLENBOURNE FARM OLD ELLENSBROOK ROAD NEAR MARGARET RIVER, -33.9167°S 115.0167°E, MARSH, L ET AL., 29-12-97, P2; C31386, DWELLINGUP NANGA STUDY SITES, -32.7667°S 116.0833°E, JUDD, S , ??-03-97, G10; C31387, WALPOLE NORNALUP NATIONAL PARK, -34.9833°S 118.7167°E, WALLIS, N., ??-??-91; C31388, KARRI VALLEY RESORT, -34 4333°S 115.8500°E, WALDOCK, J. M., 21-10-97, L41; C31389, SHENTON PARK SHENTON PARK BUSH, -31 9644°S 115.7992°E, BERRY, P. F., ??-11-98, P2, C31390, MT LESUEUR 4 5 KM E, -30.1667°S 115.2500°E, UWA 27 RS, 11-07-89; C31391, STIRLING RANGE NATIONAL PARK SOUTH FACE OF PYONGURUP PEAK, -34.3714°S 118.3222°E, HARVEY, M S. ET AL., 04-09-96, P3, C31392, STIRLING RANGE NATIONAL PARK NEAR WEST END OF ELLEN TRACK, -34 3614°S 118.2883°E, HARVEY, M. S., WALDOCK, J. M. & MAIN, B. Y., 18-12-96, P3; C31393, STIRLING RANGE NATIONAL PARK WEST END OF ELLEN TRACK, -34.3644°S 118.2881°E, HARVEY, M. S. ET AL., 04-09-96, P3; C31394/99, GLENBOURNE FARM OLD ELLENSBROOK ROAD NEAR MARGARET RIVER, -33.9167°S 115.0167°E, MARSH, L. ET AL., 20-05-98, P2, C31400/2, GLENBOURNE FARM OLD ELLENSBROOK ROAD NEAR MARGARET RIVER, -33.9167°S 115.0167°E, MARSH, L. ET AL., 11-07-98, P2, C31403/4, WALPOLE NORNALUP NATIONAL PARK JARRAH FOREST, -34.9917°S 116.7083°E, VAN HEURCK, P. ET AL , 13-05-97, L40; C31405, WALPOLE NORNALUP NATIONAL PARK JARRAH FOREST, -34 9917°S 116.7083°E, VAN HEURCK, P. ET AL , 13-05-97, L10; C31406, WALPOLE NORNALUP NATIONAL PARK KARRI FOREST, -35 0000°S 116 7167°E, VAN HEURCK, P ET AL., 13-05-97, G30; C31407, WALPOLE NORNALUP NATIONAL PARK KARRI FOREST, -34.9833°S 116.7083°E, VAN HEURCK, P. ET AL , 13-05-97, L40; C31408, WALPOLE NORNALUP NATIONAL PARK KARRI FOREST, -34.9833°S 116.7083°E, VAN HEURCK, P. ET AL., 13-05-97, L10, C31409, WALPOLE NORNALUP NATIONAL PARK KARRI FOREST, -34 9833°S 116.7083°E, VAN HEURCK, P ET AL., 13-05-97, G30; C31410, WALPOLE NORNALUP NATIONAL PARK TINGLE UPLAND FOREST, -34.9917°S 116 6500°E, VAN HEURCK, P. ET AL., 20-05-97, L10; C31411, WALPOLE NORNALUP NATIONAL PARK TINGLE CREEK FOREST, -34.9917°S 116.6583°E, VAN HEURCK, P. ET AL., 20-05-97, L10; C31412, WALPOLE NORNALUP NATIONAL PARK TINGLE UPLAND FOREST, -34.9583°S 116 7750°E, VAN HEURCK, P. ET AL., 16-05-97, L40; C31413, WALPOLE NORNALUP NATIONAL PARK TINGLE UPLAND FOREST, -34.9583°S 116.7750°E, VAN HEURCK, P. ET AL., 16-05-97, L10, C31414, WALPOLE NORNALUP NATIONAL PARK TINGLE UPLAND FOREST, -34 9583°S 116.7750°E, VAN HEURCK, P. ET AL., 16-05-97, G30; C31415, WALPOLE NORNALUP NATIONAL PARK TINGLE CREEK FOREST, -34.9583°S 116 8000°E, VAN HEURCK, P. ET AL., 14-05-97, L40; C31416, WALPOLE NORNALUP NATIONAL PARK TINGLE CREEK FOREST, -34 9583°S 116.8000°E, VAN HEURCK, P. ET AL., 14-05-97, L10; C31417, CAPE LEEUWIN SWAMP WEST EDGE OF SWAMP EITHER SIDE OF WOODEN FLUME, -34.3667°S 115 1333°E, SLACK-SMITH, S. ET AL , 19-08-90, L90, C31418, CAPE LEEUWIN SWAMP NORTHWEST OF SWAMP ON SLIGHT RISE, -34.3667°S 115.1333°E, SLACK-SMITH, S. ET AL, 20-08-00, S1, C31419/20, GLENBOURNE FARM OLD ELLENSBROOK ROAD NEAR MARGARET RIVER, -33.9167°S 115 0167°E, MARSH, L. ET AL., 26-10-98, P2; C31421/7, GLENBOURNE FARM OLD ELLENSBROOK ROAD NEAR MARGARET RIVER, -33 9167°S 115 0167°E, MARSH, L ET AL , 01-11-99, P2, C31929, WOODMAN POINT, -32 1328°S 115 7581°E, WALDOCK, J. M. & LONGBOTTOM, A. F., 04-11-94,

P3; C31930, WOODMAN POINT, -32.1328°S 115.7581°E, HARVEY, M S. & WALDOCK, J M., 19-01-95, P3, C31931, WOODMAN POINT, -32.1328°S 115 7581°E, HARVEY, M. S. & WALDOCK, J. M., 04-05-95, P3; C31932, MT HENRY, -32.0314°S 115.8622°E, WALDOCK, J M. & LONGBOTTOM, A F., 04-11-94, P3, C31933, BOLD PARK, -31 9417°S 115.7742°E, WALDOCK, J M , 24-09-93, P3, C31934, BOLD PARK, -31 9414°S 115.7669°E, WALDOCK, J M. ET AL., 18-11-93, P3, C31935, BOLD PARK, -31.9417°S 115 7742°E, WALDOCK, J. M. ET AL., 18-11-93, P3; C31936, JANDAKOT AIRPORT, -32.0919°S 115.8744°E, WALDOCK, J. M & LONGBOTTOM, A F., 01-09-94, P3; C31937, JANDAKOT AIRPORT, -32.0919°S 115.8744°E, WALDOCK, J. M. & HARVEY, M. S , 21-03-95, P3, C31938, JANDAKOT AIRPORT, -32 0933°S 115.8775°E, WALDOCK, J M. & HARVEY, M S., 21-03-95, P3, C31939, JANDAKOT AIRPORT, -32 0933°S 115 8775°E, WALDOCK, J. M. & HARVEY, M S., 06-07-95, P3; C31940, JANDAKOT AIRPORT, -32.0933°S 115 8775°E, WALDOCK, J. M. & HARVEY, M. S., 04-05-95, P3, C31941, JANDAKOT AIRPORT, -32 0933°S 115 8775°E, WALDOCK, J. M. & LONGBOTTOM, A F., 04-11-94, P3; C31942, HEPBURN HEIGHTS, -31.8183°S 115 7672°E, WALDOCK, J. M. & HARVEY, M S., 29-01-96, P3; C31943, HEPBURN HEIGHTS, -31.8183°S 115 7672°E, WALDOCK, J. M. & HARVEY, M S , 28-11-95, P3; C31944, NORMAN ROAD, CARDUP, -32 2672°S 116.0122°E, WALDOCK, J. M., WEST, P. L. & LONGBOTTOM, A., 17-06-96, P3, C31945, CARDUP RESERVE, -32.2431°S 115.9856°E, WALDOCK, J. M., WEST, P L & LONGBOTTOM, A., 17-06-96, P3; C31946, CARDUP RESERVE, -32.2444°S 115 9875°E, WALDOCK, J. M , WEST, P. L & LONGBOTTOM, A., 17-06-96, P3; C31947, TRIGG DUNE BUSH, -31.8692°S 115.7606°E, WALDOCK, J. M. & HARVEY, M S., 28-11-95, P3.

Diagnosis: Habitus runner. Animal large (can be > 10 mm) with strong colouring and of terrestrial origin. Animal broad with base colouring of cream with brown patterning. Pereonal epimera cream coloured. Pleopod exopodites of female sub-rectangular and with distinct markings. Pleopod exopodites 1 and 2 only slightly pointed on inner border.

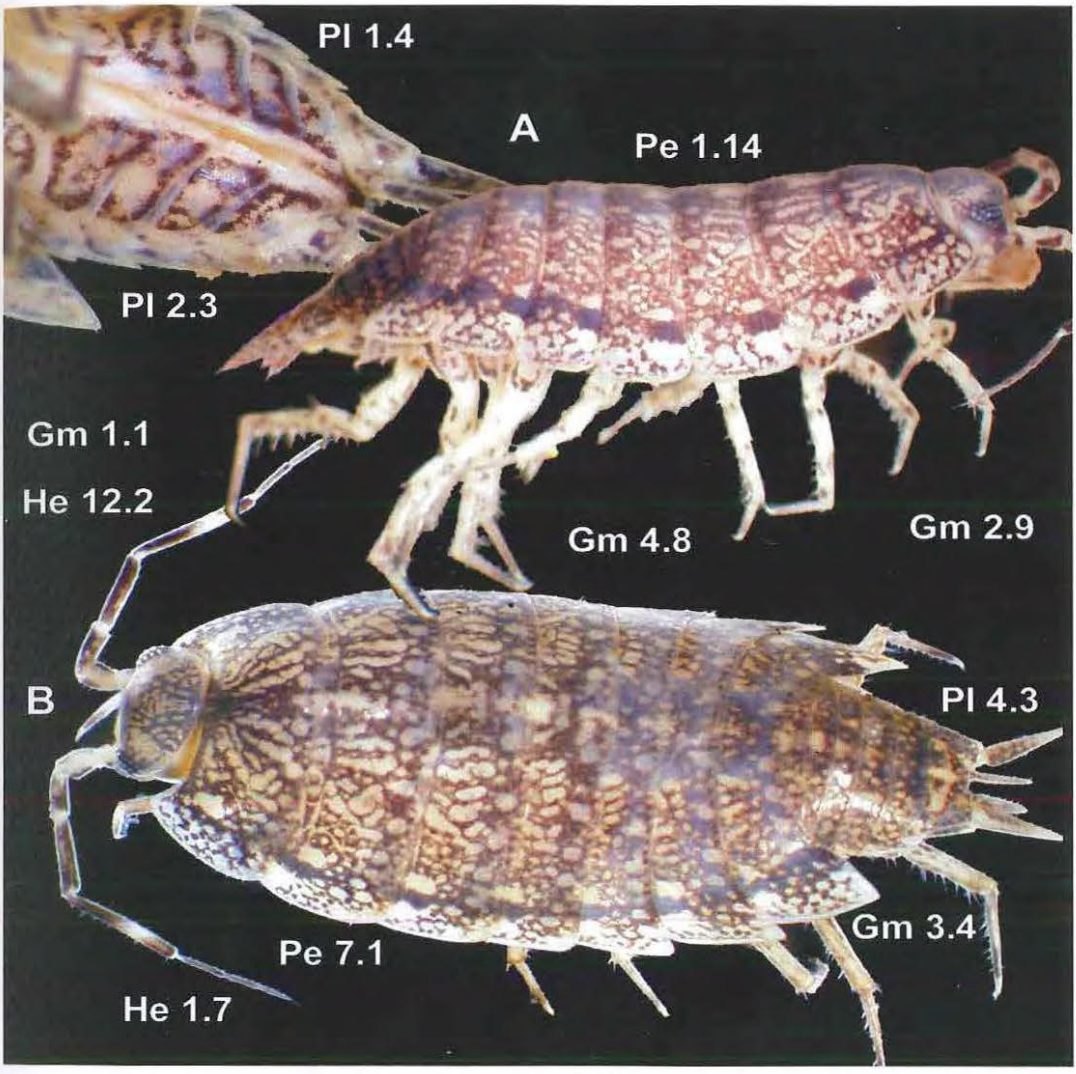


Plate 3.71. Laevophiloscia **species 2 from (A) jarrah forest at Lepers Gully Road near Dwellingup (C30366) (length 11 mm) and from (B) Harvey River at the bridge on Harvey-Quindanning Road (C30398) (length 10 mm).**

3.17. FAMILY ARMADILLIDAE BRANDT AND RATZBERG

Diagnosis: Conglobating and typically strongly convex. Flagellum of second antenna with 2 articles. Frontal line of head forms a ridge. Body outline not interrupted between pleon and pereon. Articulatory lobes present on epimera 1 & 2. Uropod flattened and occupying space between pleonal epimeron 5 and telson. Exopodite of uropod attached on dorsal surface or near anterior inner border of protopodite, or absent. Pleopodal lungs present in exopodites 1-5 or 1-4 in Buddelundia. Exopodites overlap each other loosely except in Buddelundia. Telson often hourglass-shaped.

FAMILY TYPE MATERIAL EXAMINED BUT UPON WHICH DIAGNOSES COULD NOT BE MADE: C393, ARMADILLO INTEGER, SYNTYPE, TORBAY, WA, HAMBURG EXPEDITION STN 162, 19/08/05. (HEAD AND PEREONAL SEGMENT 1 MISSING THEREFORE NO DETERMINATIONS POSSIBLE FOR THIS SPECIES).

MATERIAL EXAMINED BUT DETERMINED ONLY TO FAMILY: C31428, GLENEAGLE BL67 HAVEL'S PLOT 169 31 MILE CREEK, -32 2500°S 116.1667°E, SPRINGETT, J. A., 18-10-71; C31429, GLENEAGLE BP80 HAVELS PLOT 108, -32.2500°S 116 1667°E, SPRINGETT, J. A., 28-10-71.

3.17.1. GENUS PSEUDODIPLOEXOCHUS ARCANGELI

Diagnosis: Conglobating animal of very small size (< 4 mm). Frontal ridge with flattened appearance not produced to obtuse point in centre. No bumps on pereonites at junction with epimera. Inner lobe of pereonal epimeron 1 very long, much longer than posterior lateral epimera border in lateral view. Inner lobe of pereonal epimeron 2 large, rounded and projecting backward much further than epimera which is pointed. Pereonal epimeron 3 produced to point. Pereonites without spines. Telson very short and wide. Uropod protopodite small and sub-rectangular. Uropod exopodites absent in species described here (for a complete diagnosis see Taiti & Ferrara, 1979).

3.17.1.1. Pseudodiploexochus species 1

Plate 3.13, He 9.1; Plate 3.72.

Hybodillo australiensis Vandel 1973

Pseudodiploexochus australiensis Taiti & Ferrara, 1979

Pseudodiploexochus sp. Judd & Horwitz, 2003

MATERIAL EXAMINED. C30500/2, MOUNT DALE, -32 0918°S 116.2779°E, WATSON, A., 01-10-01, P3, C30503, MOUNT DALE, -32 0918°S 116.2779°E, JUDD, S. & WATSON, A., 26-06-01, G10; C30504/6, MOUNT DALE, -32.0878°S 116.2784°E, WATSON, A., 01-10-01, P3; C30508, CHITTERING LAKE RESERVE, -31.4180°S 116 0930°E, JUDD, S., 08-08-98, B40; C30509, MOGANMOGANNING NATURE RESERVE, -31.1200°S 116 2530°E, JUDD, S., 11-10-98, L10; C30510, LUPTON CONSERVATION PARK NORTH, -32.4470°S 116.6430°E, JUDD, S., 26-10-98, L10; C30511, JINGALUP NATURE RESERVE, -34 0130°S 117.0130°E, JUDD, S., 29-10-98, R1; C30512, OCCIDENTAL FOREST BLOCK DALE ROAD, -32.1050°S 116 2570°E, JUDD, S., 04-11-98, L10; C30513, OCCIDENTAL FOREST BLOCK DALE ROAD, -32.1050°S 116 2570°E, JUDD, S., 04-11-98, L20; C30514, MARGARET RIVER CREEK, -33 9350°S 115 0650°E, JUDD, S., 10-12-98, L10; C30515, MARGARET RIVER CREEK, -33 9350°S 115 0650°E, JUDD, S., 10-12-96, B10; C30516, RATE BLOCK, -34.8350°S 117.0070°E, JUDD, S., 01-09-99, L10; C30517, ORDNANCE STATE FOREST, -34.8680°S 116.6650°E, JUDD, S., 10-01-99, L10; C30518, MOUNT FRANKLAND NATIONAL PARK CROSSING BLOCK, -34 8030°S 116.8830°E, JUDD, S., 10-01-99, L10; C31430, PEMBERTON HV64 MARRI RD, -34.5000°S 118 0833°E, SPRINGETT, J. A., 03-12-71; C31431, ARMADALE, -32.1500°S 116 0000°E, COLLECTOR UNKNOWN, 08-08-32; C31432, GNOOCARDUP, -33.9333°S 115 0000°E, SLACK-SMITH, S., 04-08-85, L50; C31433/4, GNOOCARDUP SEEP LEEUWIN NATURALISTE NATIONAL PARK, -33.9333°S 115 0000°E, SLACK-SMITH, S., 26-11-85, L50, C31435/6, GNOOCARDUP, -33.9333°S 115.0000°E, SLACK-SMITH, S., 04-08-85; C31437, GNOOCARDUP, -33.9333°S 115.0000°E, SLACK-SMITH, S., 04-08-85, L50, C31438, MT COOKE, -32.4167°S 116.3000°E, HARVEY, M. S. & WALDOCK, J. M., 19-09-

91, L10; C31439, MT COOKE, -32.4167°S 116.3000°E, HARVEY, M. S. & WALDOCK, J. M., 25-02-92, L10; C31440, NINDUP W OF WITCHCLIFFE, -34.0500°S 115.0500°E, WALDOCK, J. M., 06-02-93, L41; C31441, NANNUP 50 KM SW OF SUE'S BRIDGE, -33.9833°S 115.7500°E, PECK, S. & PECK, J., 26-07-80, L20; C31442, GNOOCARDUP, -33.9333°S 115.0000°E, SLACK-SMITH, S., 04-08-85; C31443, PORONGURUP NATIONAL PARK S END OF MILLINUP PASS, -34.7000°S 117.9000°E, HARVEY, M. S. & WALDOCK, J. M., 31-03-93, L10; C31444, TORNDIRRUP NATIONAL PARK GULLY OUTSIDE N. EDGE ON LIMEBURNERS RD, -35.0833°S 117.9000°E, HARVEY, M. S. & WALDOCK, J. M., 26-03-93, B10; C31445, DENMARK, -34.9500°S 117.3500°E, WOMMERSLEY, W., ??-??-??; C31446, 4.75 KM ESE OF MARGARET RIVER, -33.9644°S 115.1228°E, PETERSON, M., 14-02-92; C31447, STIRLING RANGE NATIONAL PARK SOUTH FACE OF PYONGURUP PEAK, -34.3714°S 118.3222°E, HARVEY, M. S. ET AL., 04-09-96, P3; C31949, WOODMAN POINT, -32.1306°S 115.7578°E, WALDOCK, J. M. & LONGBOTTOM, A. F., 01-09-94, P3; C31950, HEPBURN HEIGHTS, -31.8186°S 115.7697°E, WALDOCK, J. M. & HARVEY, M. S., 28-11-95, P3; C31951, HEPBURN HEIGHTS, -31.8183°S 115.7672°E, WALDOCK, J. M. & HARVEY, M. S., 28-11-95, P3; C31952, MT CLAREMONT, -31.9611°S 115.7667°E, WALDOCK, J. M. & HARVEY, M. S., 06-07-95, P3.

Diagnosis: Habitus roller. No bumps on pereonites at junction with epimera and without bumps on dorsal surface of pereonite 6 & 7.

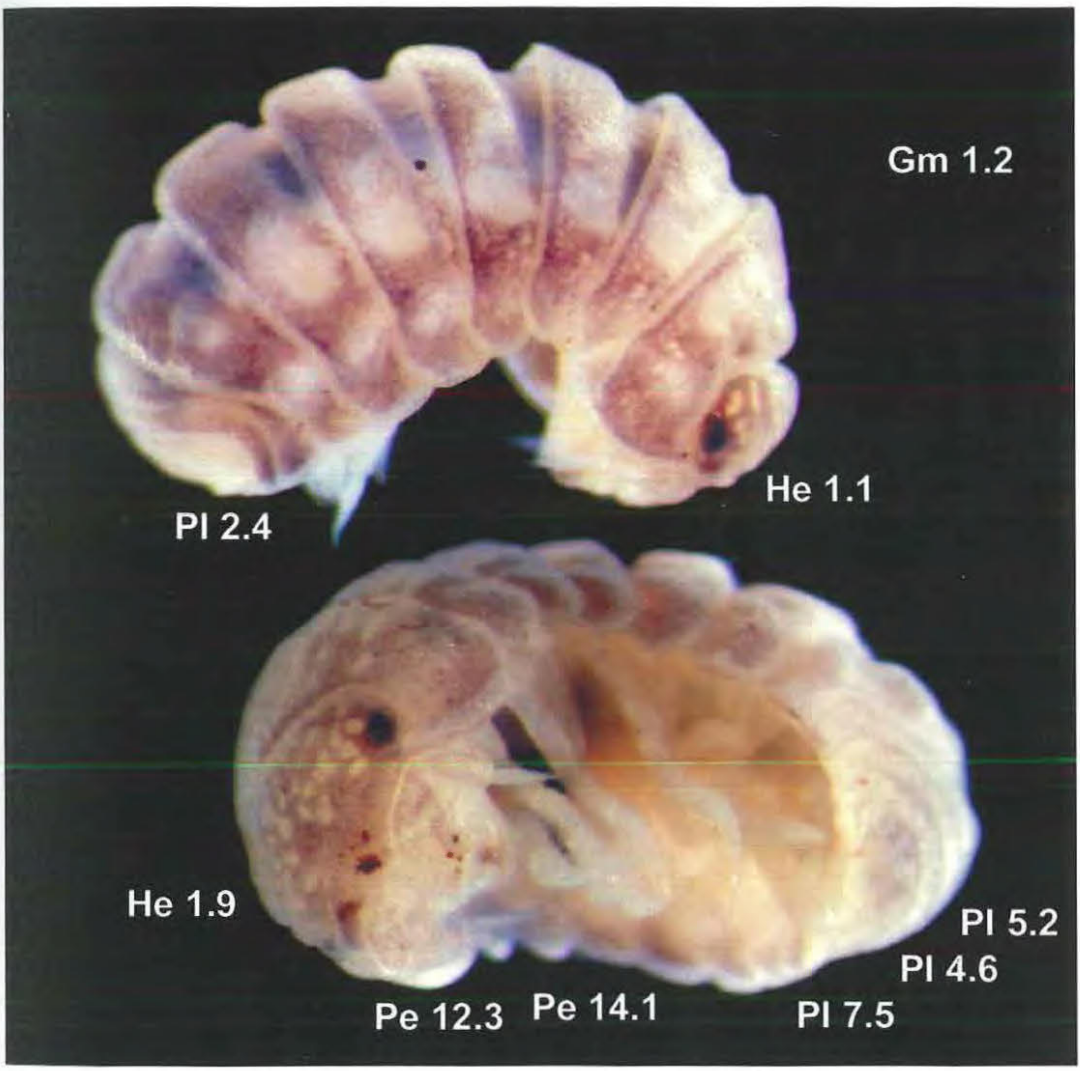


Plate 3.72. Pseudodiploexochus species 1 from Margaret River (C30514) (length 2 mm).

3.17.1.2. Pseudodiploexochus species 2

Plate 3.17, Pe 1.18; Plate 3.19, Pe 3.2; Plate 3.73.

Pseudodiploexochus sp. Judd & Horwitz, 2003

Pseudolaureola sp. 5 Judd & Horwitz, 2003

MATERIAL EXAMINED: C18406, WALPOLE INLET CAMP SITE, -34 9833°S 116 7333°E, NICHOLLS COLLECTION, 12-01-33; C18417, FRANKLAND RIVER, -35.0000°S 116.8167°E, NICHOLLS COLLECTION, 11-01-33; C30507, KARNET BROOK, -32.4070°S 116.0270°E, JUDD, S., 29-07-98, L10; C30519. WELLINGTON MILL, -33 4430°S 115 9080°E, JUDD, S , 30-07-98, L10; C30520, MT LENNARD, -33 3920°S 115.8870°E, JUDD, S , 30-07-98, L10; C30521, CHITTERING LAKE RESERVE, -31.4180°S 116.0930°E, JUDD, S., 08-08-98, B30, C30522, WALYUNGA NATIONAL PARK, -31.7320°S 116.0730°E, JUDD, S., 21-08-98, L10; C30523, BOONANARING NATURE RESERVE, -31 2500°S 115.9100°E, JUDD, S , 07-10-98, L10; C30524, MOUNT BYROOMANNING NR, -31.3730°S 116 1270°E, JUDD, S , 18-10-98, L40, C30525, MONADNOCKS CONSERVATION PARK MARGINATA ROAD, -32 2420°S 116.2050°E, JUDD, S., 04-11-98, L10; C30526, LEPERS GULLY ROAD, -32.8470°S 116 1080°E, JUDD, S., 10-11-98, L10; C30527, LUDLOW TUART FOREST, -33 6150°S 115 4670°E, JUDD, S., 25-11-98, G30; C30528, HARVEY RIVER BRIDGE AT QUINDANNING ROAD, -33.0830°S 115.9830°E, JUDD, S., 26-11-98, L10; C30529, MARBELUP NATURE RESERVE, -34.9920°S 117.7220°E, JUDD, S., 17-12-98, B40; C30530, TORNDIRRUP NATIONAL PARK, -35 1150°S 117.9330°E, JUDD, S , 18-12-98, L10; C30531, PARDELUP NATURE RESERVE, -34 6720°S 117 4150°E, JUDD, S., 20-12-98, L10; C30532, RATE BLOCK, -34.8350°S 117 0070°E, JUDD, S , 01-09-99, B10; C30533, RATE BLOCK, -34 8350°S 117.0070°E, JUDD, S., 01-09-99, L41; C30534, ORDNANCE STATE FOREST, -34.8680°S 116.6650°E, JUDD, S , 10-01-99, L10; C30535, LONGTHOMPSON BLOCK, -34.6600°S 116 7030°E, JUDD, S , 11-01-99, L10; C30536, SHANNON NATIONAL PARK (FISH CREEK ROAD), -34.6250°S 116.4370°E, JUDD, S., 27-01-99, L10; C30537, SHANNON NATIONAL PARK (FISH CREEK ROAD), -34.6250°S 116 4370°E, JUDD, S., 27-01-99, L20; C30538, MT CHUDALUP, -34.7630°S 116 0830°E, JUDD, S., 28-01-99, L10, C30539, CHALK BROOK (LANE POOLE RESERVE), -33 0670°S 116.2320°E, JUDD, S., 28-11-98, L10; C30540, MT LINDESAY (WEST SIDE), -34.8630°S 117.3180°E, JUDD, S., 08-01-99, L20; C30541, MT LINDESAY (WEST SIDE), -34 8630°S 117.3180°E, JUDD, S., 08-01-99, G20, C30543, MOUNT DALE, -32 1220°S 116.2926°E, WATSON, A., 01-10-01, P3; C30544, MOUNT DALE, -32.1028°S 116.2861°E, WATSON, A., 01-10-01, P3; C31448, GLENEAGLE BL67 HAVEL'S PLOT 169, -32.2500°S 116.1667°E, SPRINGETT, J. A , 18-10-71; C31449, GLENEAGLE BO68, -32.2500°S 118.1667°E, SPRINGETT, J. A., 18-10-71; C31450, TWO PEOPLES BAY TICK FLAT WEATHER STATION, -34 9833°S 118 1667°E, BURBIDGE, A. A. & SPRINGETT, J A., 16-10-70; C31451, GLENEAGLE BL68 HAVELS PLOT 166, -32.2500°S 116.1667°E, SPRINGETT, J. A., 18-10-71; C31452, GNOOCARDUP SEEP LEEUWIN NATURALISTE NATIONAL PARK W. EDGE, -33.9333°S 115.0000°E, SLACK-SMITH, S., 26-11-85, L90; C31453, TORNDIRRUP NATIONAL PARK 9 KM S. OF ALBANY, -35.0900°S 117.8333°E, DYER, P. H. & LYON, J. L., 09-11-83, P1; C31454, MT COOKE, -32.4167°S 116 3000°E, HARVEY, M. S. & WAI DOCK, J. M , 31-07-91, L10; C31455, YANCHEP NATIONAL PARK BOOMERANG GORGE, -31.5333°S 115.6167°E, WALDOCK, J. M. & SAMPEY, A., 20-04-93, L10, C31458, SHANNON NATIONAL PARK DOG POOL ON SHANNON RIVER, -34 7500°S 116 3667°E, HARVEY, M. S. & WALDOCK, J. M., 30-04-90, B10; C31457, DEEP RIVER, -35.0000°S 116.6667°E, NICHOLLS COLLECTION, 31-12-32; C31458, DENMARK 17 KM NORTH ON MT BARKER RD, -34 6167°S 117.3500°E, MANN, P. J., 18-03-90, C31459/60, GUNJUN GULLY, -31.9833°S 116.1333°E, WALDOCK, J. M., 08-11-88, L10; C31461, WALPOLE ROAD TO WALPOLE NEAR LAND LEACH GULLY, -34.9833°S 116.7167°E, NICHOLLS COLLECTION, 23-11-38; C31462, SWARBRICK'S TRACK VIA ALBANY, -35.0000°S 116.8167°E, NICHOLLS COLLECTION, 03-01-33, C31463/4, WALPOLE NORNALUP NATIONAL PARK, -34.9833°S 116 7167°E, WALLIS, N., ??-??-91; C31465, STIRLING RANGE NATIONAL PARK CARAVAN PARK, -34 3167°S 118.2000°E, HARVEY, M. S & WALDOCK, J. M., 02-04-93, L42; C31466, THOMPSON'S ROAD PADDOCK, TEA TREE SWAMP, -34.5142°S 116.6414°E, HORWITZ, P. ET AL., ??-07-94, L80; C31467, INLET RIVER SEDGELAND SWAMP, -34.9175°S 116.5872°E, HORWITZ, P ET AL., ??-01-94, L80; C31468/9, MT DALE WITHIN 300M OF SUMMIT, -32.1333°S 116 3000°E, JUDD, S., 29-03-00, P3; C31948, TALBOT ROAD RESERVE, -31.8736°S 116.0508°E, WALDOCK, J M., 17-05-93, L70, C31953, WOODMAN POINT, -32.1328°S 115.7581°E, WALDOCK, J. M. & LONGBOTTOM, A. F., 04-11-94, P3; C31954/5, WOODMAN POINT, -32 1328°S 115 7581°E, WALDOCK, J. M & LONGBOTTOM, A. F., 01-09-94, P3; C31956, WOODMAN POINT, -32.1306°S 115.7578°E, WALDOCK, J. M. & LONGBOTTOM, A. F., 04-11-94, P3; C31957, BOLD PARK, -31.9372°S 115.7711°E, HARVEY, M S & WALDOCK, J. M., 20-07-93, P3; C31956, BOLD PARK, -31 9353°S 115 7750°E, HARVEY, M. S. & WALDOCK, J. M., 20-07-93, P3; C31959, BOLD PARK, -31.9372°S 115.7711°E, WALDOCK, J. M , 24-09-93, P3; C31960, BOLD PARK, -31 9372°S 115.7711°E, WALDOCK, J. M. ET AL., 19-11-93, P3; C31961, BOLD PARK, -31.9364°S 115.7639°E, WALDOCK, J M. ET AL., 18-11-93, P3; C31962, HARTFIELD PARK, -32 0000°S 115.9953°E, WALDOCK, J M., WEST, P. L. & LONGBOTTOM, A., 17-06-96, P3; C31963, HARTFIELD PARK, -31 9978°S 115.9944°E, WALDOCK, J M., WEST, P L. & LONGBOTTOM, A., 17-06-96, P3; C31964, JANDAKOT AIRPORT, -32.0919°S 115 8744°E, WALDOCK, J. M. & HARVEY, M. S., 19-01-95, P3, C31965, JANDAKOT AIRPORT, -32 0919°S 115 8744°E, WALDOCK, J. M. & LONGBOTTOM, A. F., 01-09-94, P3; C31966, JANDAKOT AIRPORT, -32 0919°S 115.8744°E, WALDOCK, J. M. & LONGBOTTOM, A. F., 04-11-94, P3, C31967, JANDAKOT AIRPORT, -32.0919°S 115.8744°E, WALDOCK, J. M. & HARVEY, M. S., 21-03-95, P3; C31968, JANDAKOT AIRPORT, -32.0933°S 115 8775°E, WALDOCK, J. M. & HARVEY, M. S., 19-01-95, P3; C31969, JANDAKOT AIRPORT, -32 0933°S 115.8775°E, WALDOCK, J M & HARVEY, M. S., 06-07-95, P3; C31970, HEPBURN HEIGHTS, -31.8158°S 115.7781°E, WALDOCK, J M. & HARVEY, M. S , 28-11-95, P3; C31971, HEPBURN HEIGHTS, -31.8183°S 115.7672°E, WALDOCK, J M. & HARVEY, M. S , 29-01-96, P3; C31972, PERTH AIRPORT, -31.9767°S 115 9744°E, WALDOCK, J. M. ET AL., 28-07-93, P3; C31973, PERTH AIRPORT, -31 9767°S 115 9744°E, WALDOCK, J. M & HARVEY, M. S., 18-03-94, P3; C31974, PERTH AIRPORT, -31 9767°S 115 9744°E, WALDOCK, J M. ET AL., 23-09-93, P3; C31975, PERTH AIRPORT, -

31.9767°S 115.9744°E, WALDOCK, J. M. ET AL., 10-05-93, P3; C31976, PERTH AIRPORT, -31.9761°S 115.9736°E, WALDOCK, J. M. ET AL., 28-07-93, P3; C31977, PERTH AIRPORT, -31.9681°S 115.9681°E, WALDOCK, J. M. ET AL., 18-11-93, P3; C31978, PERTH AIRPORT, -31.9681°S 115.9681°E, WALDOCK, J. M. ET AL., 24-06-93, P3; C31979, PERTH AIRPORT, -31.9675°S 115.9697°E, WALDOCK, J. M., GOODSELL, J. & WEBB, J., 06-01-94, P3; C31980, PERTH AIRPORT, -31.9675°S 115.9697°E, WALDOCK, J. M. & HARVEY, M. S., 24-06-93, P3; C31981, PERTH AIRPORT, -31.9675°S 115.9697°E, WALDOCK, J. M. & HARVEY, M. S., 18-03-94, P3; C31982, PERTH AIRPORT, -31.9675°S 115.9697°E, WALDOCK, J. M. ET AL., 11-18-93, P3; C31983, MT CLAREMONT, -31.9611°S 115.7667°E, WALDOCK, J. M. & LONGBOTTOM, A. F., 01-09-94, P3; C31984, MT CLAREMONT, -31.9611°S 115.7667°E, WALDOCK, J. M. & LONGBOTTOM, A. F., 04-11-94, P3; C31985, MT CLAREMONT, -31.9608°S 115.7656°E, WALDOCK, J. M. & LONGBOTTOM, A. F., 01-09-94, P3; C31986, TALBOT ROAD RESERVE, -31.8681°S 116.0511°E, WALDOCK, J. M. & HARVEY, M. S., 24-06-93, P3; C31987, TALBOT ROAD RESERVE, -31.8681°S 116.0511°E, WALDOCK, J. M. ET AL., 18-11-93, P3; C31988, TALBOT ROAD RESERVE, -31.8733°S 116.0478°E, WALDOCK, J. M., 10-12-93, P3; C31989, TALBOT ROAD RESERVE, -31.8731°S 116.0461°E, WALDOCK, J. M., 10-12-93, P3; C31990, BOLD PARK, -31.9414°S 115.7669°E, WALDOCK, J. M., 24-09-93, P3; C32298, SCARP ROAD NEAR NORTH DANDALUP, -32.5600°S 116.0050°E, JUDD, S., 29-07-98, L10.

Diagnosis: Habitus roller. Pereonites with shallow bumps on all pereonites but most prominent on 6 & 7. Dorsal surface of head slightly bumpy.

Remarks: The arrangement of the bumps on the dorsal surface of this species is similar to those P. pacificus Lewis, 1998a (Fig. 11A). This species differs from P. pacificus in that dorsal bumps are not spherical and the ommatidia are not formed in a line.

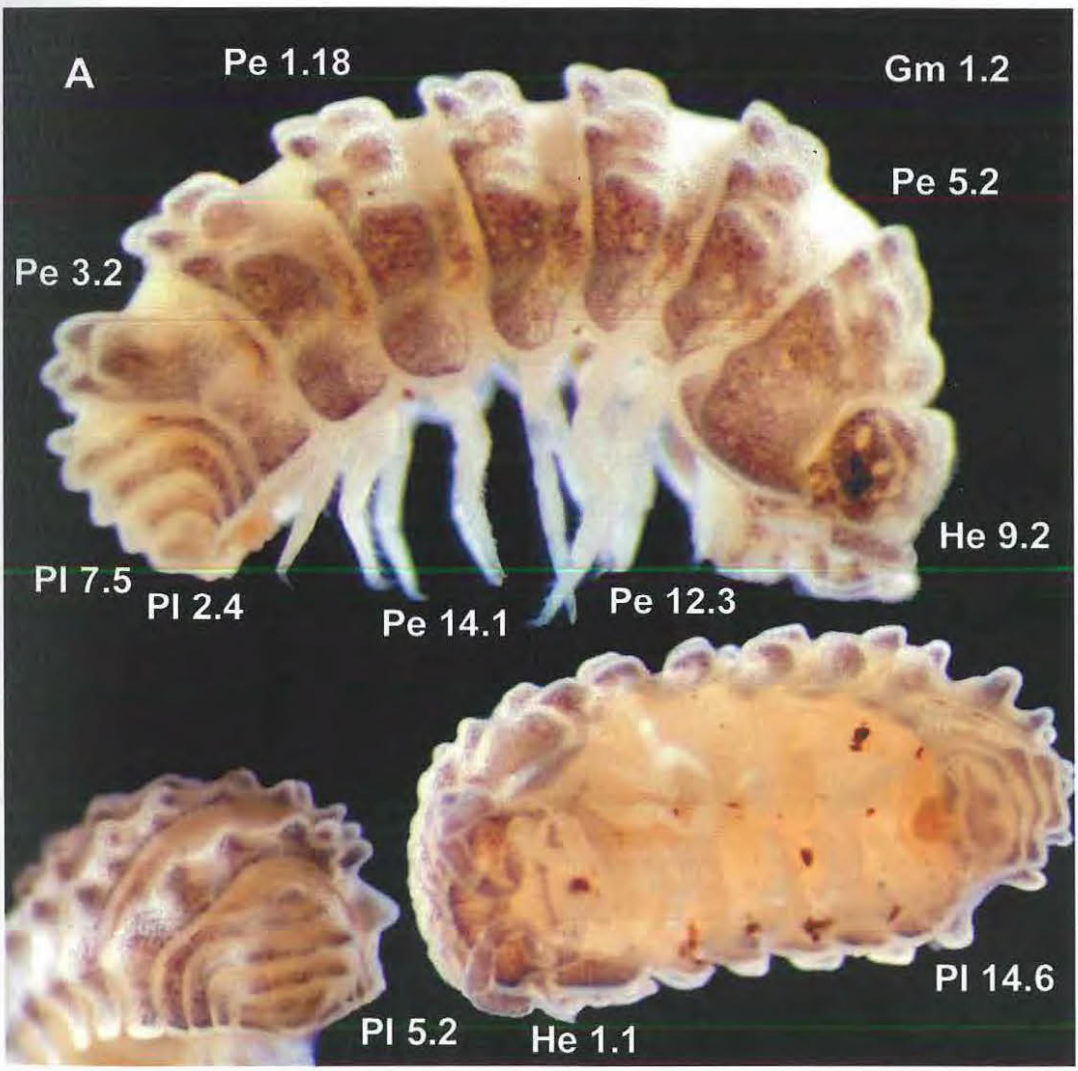


Plate 3.73. Pseudodiploexochus species 2 from jarrah forest at the west side of Mount Lindesay (C30540) (length 2 mm).

3.17.1.3. Pseudodiploexochus species 3

Plate 3.17, Pe 1.19; Plate 3.74.

Pseudodiploexochus sp. Judd & Horwitz, 2003

MATERIAL EXAMINED: C30542, SCARP ROAD NEAR NORTH DANDALUP, -32.5600°S 116.0050°E, JUDD, S., 29-07-98, L10.

Diagnosis: Habitus roller. All pereonites with pronounced bumps terminating in fine setae. Row of bumps on pereonites at junction with epimera conspicuous.

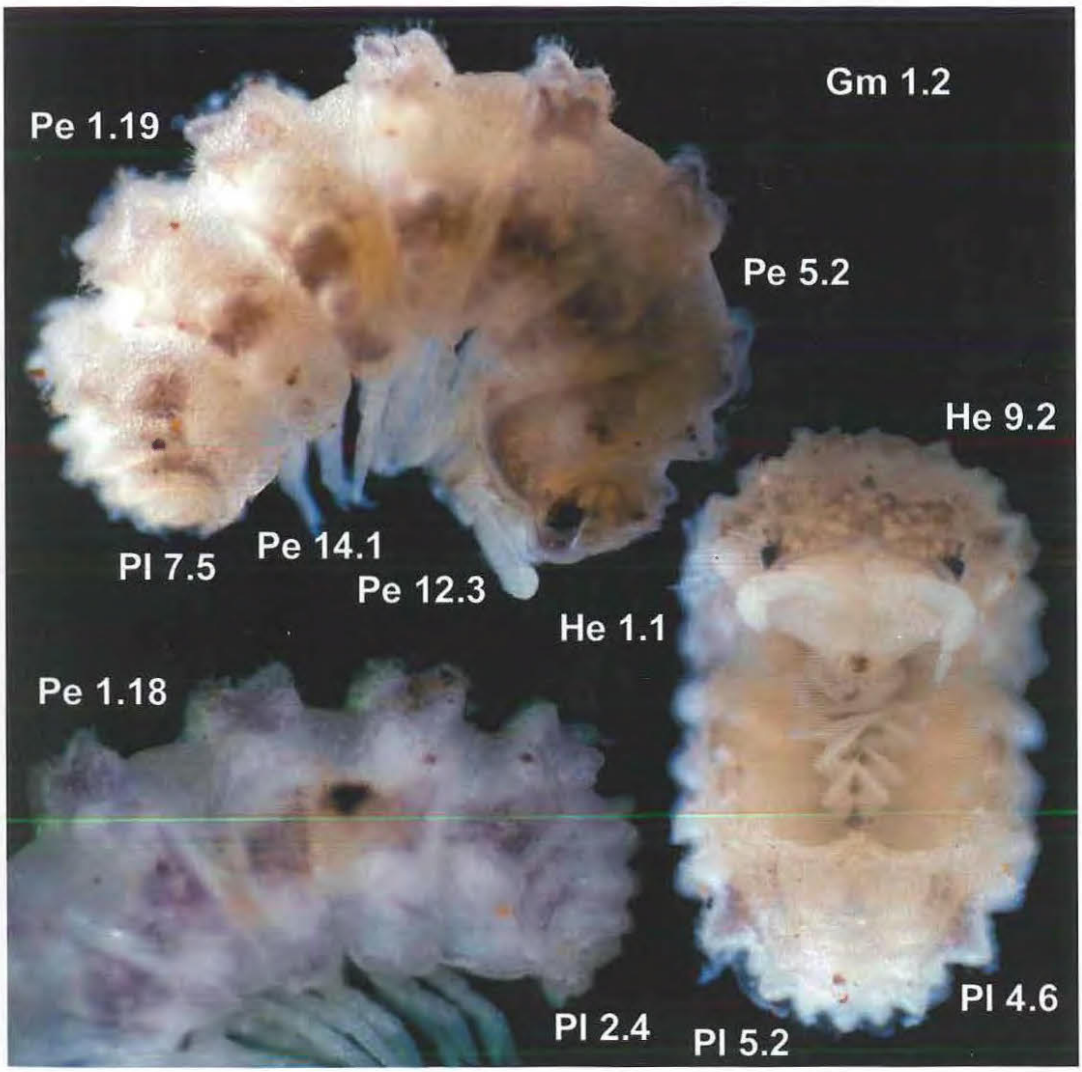


Plate 3.74. Pseudodiploexochus species 3 from jarrah forest at Del Park Road near North Dandalup (C30542) (length 2 mm).

3.17.2. GENUS PSEUDOLAUREOLA KWON, FERRARA AND TAITI

UNDETERMINED MATERIAL EXAMINED· C31470, THE CASCADES 8 KM SSW PEMBERTON, -34.5000°S 116 0000°E, HARVEY, M. S. & WALDOCK, J. M., 03-05-90, B10, C31471, SHANNON NATIONAL PARK DOG POOL ON SHANNON RIVER, -34 7667°S 116 3667°E, HARVEY, M. S. & WALDOCK, J. M., 30-04-90, B10.

Diagnosis: Conglobating animal of small or medium size (> 4 mm). Frontal ridge produced to an obtuse point in the centre. Bumps or spines on pereonites at junction with epimera. Dorsal surface with spines (except species 3 which has large spherical bumps terminating in fine setae). Inner lobe of pereonal epimeron 1 very long, much longer than posterior lateral epimera border in lateral view. Inner lobe of pereonal epimeron 2 large, rounded and projecting backward much larger than epimera which is pointed. All pereonal epimera with a foliate appearance. Telson very short and wide. Uropod protopodite sub-rectangular. Uropod exopodites absent.

Remarks: A complete diagnosis of the genus is given by Vandel (1973, p. 157-8) as Laureola (see Subsection 3.2.4 for explanation of this) and amended by Dalens (1998 p. 94).

3.17.2.1. Pseudolaureola new species 1

Plate 3.13, He 9.2; Plate 3.28, Pe 12.3; Plate 3.34, Pl 1.6; Plate 3.75.

Pseudolaureola sp. 4 Judd & Horwitz, 2003

MATERIAL EXAMINED BUT DETERMINED ONLY TO GENUS C30580, HARRIS DAM, -33 2550°S 116 1150°E, JUDD, S., 30-10-98, L10, C30581, LEPERS GULLY ROAD, -32 8470°S 116 1080°E, JUDD, S., 10-11-98, L10.

Diagnosis: Habitus roller. Dorsal surface of head with spines. Pereonites with long spines. Pereonal epimeron 7 with terminal spine but pleonal epimera without terminal spines.

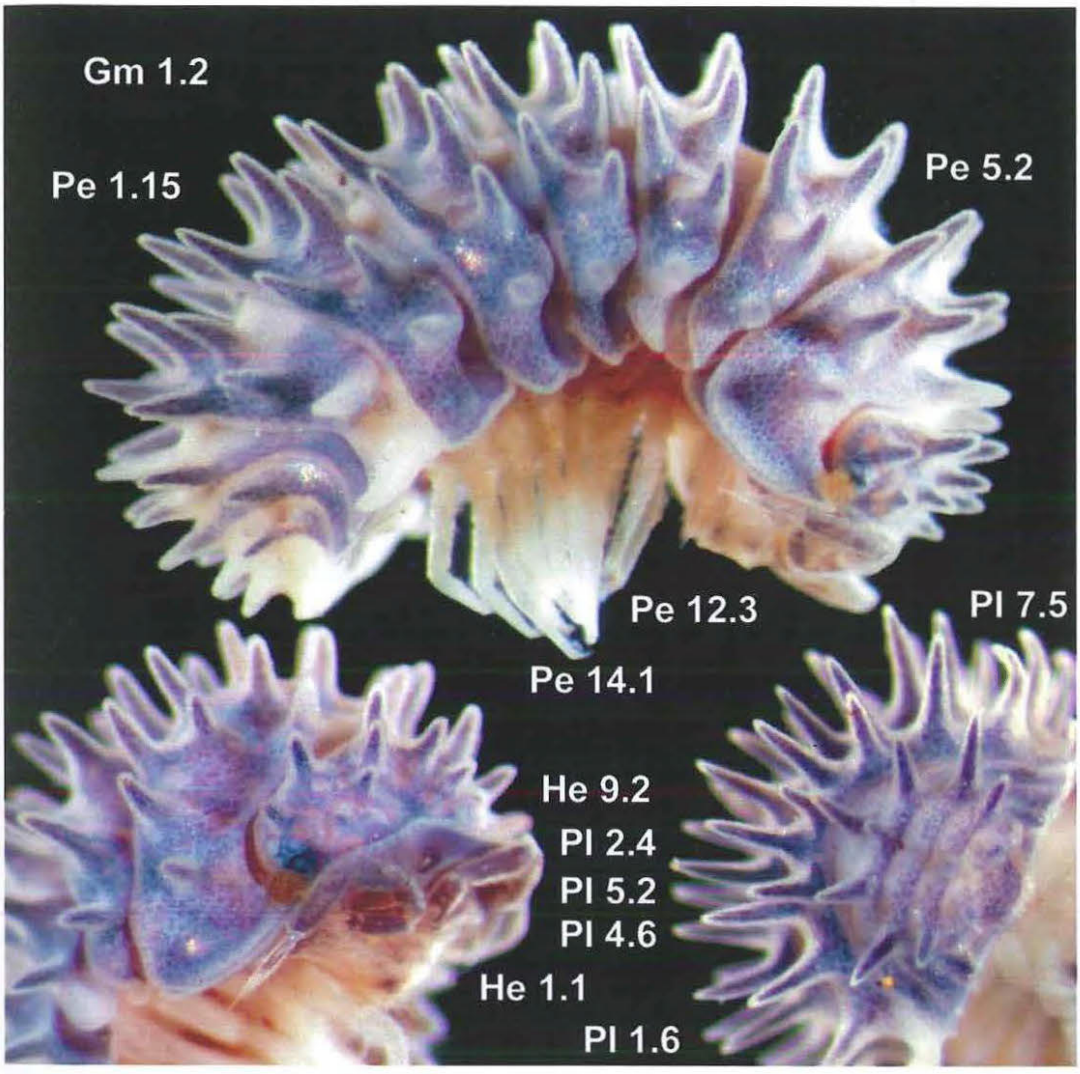


Plate 3.75. Pseudolaureola species 1 from jarrah forest near Harris Dam (C30580) (length 3 mm).

3.17.2.2. Pseudolaureola new species 2

Plate 3.13, He 9.3; Plate 3.76

Pseudolaureola sp. 1 Judd & Horwitz, 2003

MATERIAL EXAMINED: C31536, SHANNON NATIONAL PARK DOG POOL ON SHANNON RIVER, -34.7667°S 116.3667°E, HARVEY, M. S. & WALDOCK, J. M., 30-04-90, P3; C31537, SHANNON NATIONAL PARK DOG POOL ON SHANNON RIVER, -34.7500°S 116.3667°E, HARVEY, M. S. & WALDOCK, J. M., 30-04-90, B10; C31538, SHANNON NATIONAL PARK DOG POOL ON SHANNON RIVER, -34.7667°S 116.3667°E, HARVEY, M. S. & WALDOCK, J. M., 30-04-90.

Diagnosis: Habitus roller. Dorsal surface of head with long spines (particularly posterior ones). Centre of frontal ridge with 2 prominent frontal projections. Pereonites with long spines. Pereonal and pleonal epimera with terminal spines.

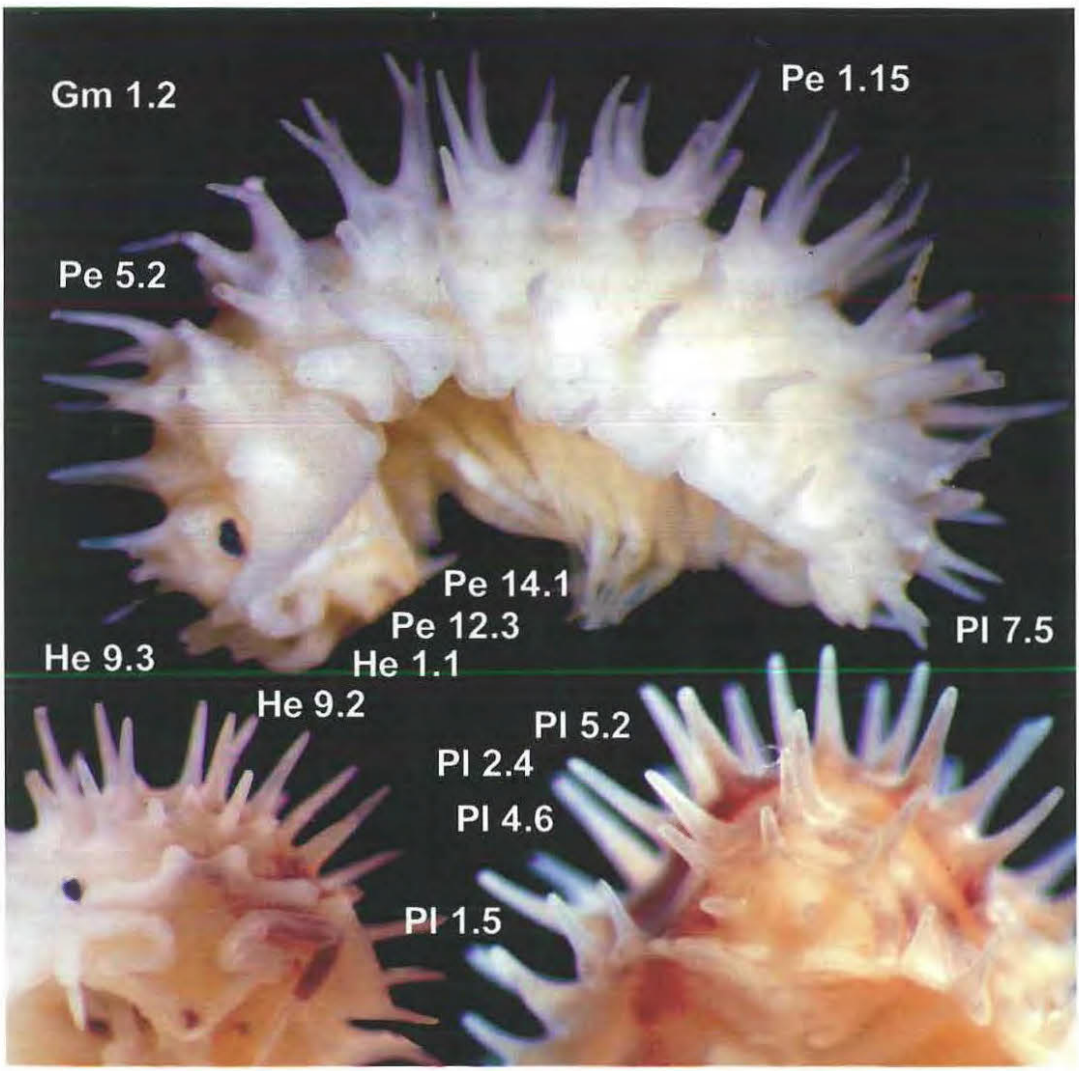


Plate 3.76. Pseudolaureola species 2 from Dog Pool, Shannon National Park (C31537/8) (some spines are broken in this illustration but it was the best of the limited material available). (length 5 mm).

3.17.2.3. Pseudolaureola wilsmorei (Nicholls & Barnes, 1926)

Plate 3.13, He 9.4; Plate 3.17, Pe 1.15; Plate 3.34, Pl 1.5; Plate 3.40, Pl 7.5; Plate 3.77.

Cubaris wilsmorei Nicholls and Barnes, 1926

Ackermania wilsmorei Barnard, 1932

Laureola wilsmorei Vandel, 1973

Pseudolaureola wilsmorei Kwon, Ferrara & Taiti, 1992

Pseudolaureola wilsmorei Dalens, 1998

Pseudolaureola wilsmorei Judd & Horwitz, 2003

MATERIAL EXAMINED C10825, SWARBRICK'S TRACK VIA ALBANY, -35 0000°S 116.8167°E, NICHOLLS COLLECTION, 04-01-33; C11019, PEMBERTON HL62 BIG BROOK 12, -34.2667°S 115.9333°E, SPRINGETT, J A., 15-11-71; C30545, WARREN NATIONAL PARK, PETTICOAT LANE, -34.5070°S 115.9130°E, JUDD, S., 13-08-98, B10; C30546, WARREN NATIONAL PARK, PETTICOAT LANE, -34.5070°S 115 9130°E, JUDD, S., 13-08-98, L20; C30547, WARREN NATIONAL PARK, PETTICOAT LANE, -34.5070°S 115 9130°E, JUDD, S., 13-08-98, L41; C30548, WARREN NATIONAL PARK, PETTICOAT LANE, -34.5070°S 115 9130°E, JUDD, S., 13-08-98, L20; C30549, WARREN NATIONAL PARK, PETTICOAT LANE, -34.5070°S 115 9130°E, JUDD, S., 13-08-98, L10; C30550, WARREN NATIONAL PARK TREAN BROOK, -34.4820°S 115 9250°E, JUDD, S., 13-08-98, L10; C30551, WARREN NATIONAL PARK TREAN BROOK, -34 4820°S 115 9250°E, JUDD, S , 13-08-98, L20; C30552, CLEAVE ROAD OFF SCOTT RD, -34.4180°S 115 7930°E, JUDD, S., 14-08-98, L50; C30553, CLEAVE ROAD OFF SCOTT RD, -34 4180°S 115.7930°E, JUDD, S , 14-08-98, L20; C30554, CLEAVE ROAD OFF SCOTT RD, -34.4180°S 115.7930°E, JUDD, S., 14-08-98, G50; C30555, BIG BROOK DAM FOREST, -34.4050°S 116.0270°E, JUDD, S , 15-08-98, B10, C30556, BIG BROOK DAM FOREST, -34.4050°S 116.0270°E, JUDD, S , 15-08-98, G40; C30557, LEEUWIN NATURALISTE NATIONAL PARK KARRI NEAR HAMELIN BAY, -34 2000°S 115 0720°E, JUDD, S., 10-12-98, L10, C30558, LEEUWIN NATURALISTE NATIONAL PARK KARRI NEAR HAMELIN BAY, -34.2000°S 115 0720°E, JUDD, S., 10-12-98, B10, C30559, LEEUWIN NATURALISTE NATIONAL PARK KARRI NEAR HAMELIN BAY, -34 2000°S 115.0720°E, JUDD, S., 10-12-98, L10; C30560, WEST CAPE HOWE NATIONAL PARK, -35.0820°S 117.6430°E, JUDD, S., 17-12-98, L42; C30561, WEST CAPE HOWE NATIONAL PARK, -35 0820°S 117.6430°E, JUDD, S., 17-12-98, L10; C30562, WEST CAPE HOWE NATIONAL PARK, -35 0820°S 117.6430°E, JUDD, S , 17-12-98, G20; C30563, WALPOLE NORNALUP NATIONAL PARK TINGLEWOOD, -35 0030°S 116.6380°E, JUDD, S., 07-01-99, L40; C30564, WALPOLE NORNALUP NATIONAL PARK TINGLEWOOD, -35.0030°S 116 6380°E, JUDD, S., 07-01-99, L10, C30565/6, ORDNANCE STATE FOREST, -34 8680°S 116.6650°E, JUDD, S., 10-01-99, L10; C30567/8, WALPOLE NORNALUP NATIONAL PARK, -34.9880°S 116 7600°E, JUDD, S., 11-01-99, L10; C30569/70, WALPOLE NORNALUP NATIONAL PARK, -34.9880°S 116 7600°E, JUDD, S., 11-01-99, L20; C31472, PEMBERTON HV61, -34 5000°S 116.0000°E, SPRINGETT, J. A., 09-11-71; C31473, SWARBRICKS?, -35.0000°S 116.8167°E, NICHOLLS COLLECTION, ??-02-??; C31474, NORNALUP NW OF SWARBRICK'S TRACK, -35.0000°S 116.8167°E, NICHOLLS COLLECTION, 08-01-33; C31475, PEMBERTON HL61 BIG BROOK 40, -34.2667°S 115.9333°E, SPRINGETT, J. A., 15-11-71; C31476, PEMBERTON HL62 BIG BROOK 12, -34 2667°S 115.9333°E, SPRINGETT, J. A., 15-11-71; C31477, PEMBERTON - MANJIMUP, -34.2500°S 116 2500°E, SPRINGETT, J A , 26-09-71, B10; C31478, PEMBERTON HO58 WARREN NATIONAL PARK, -34.4167°S 115.9167°E, SPRINGETT, J. A., 19-05-70, B10; C31479, PEMBERTON HL61 BIG BROOK, -34 2667°S 115.9333°E, SPRINGETT, J. A , ??-??-72; C31480, PEMBERTON HU61, -34.5000°S 116 0000°E, SPRINGETT, J. A., 09-11-71; C31481, PEMBERTON HN55 BEEDALUP FALLS, -34.4167°S 115.9167°E, SPRINGETT, J. A., 27-07-69, C31482, PEMBERTON WARREN NATIONAL PARK, -34.4167°S 115.9167°E, SPRINGETT, J. A., 19-05-70, B10, C31483, PEMBERTON HQ58 WARREN NATIONAL PARK, -34.4167°S 115 9167°E, SPRINGETT, J. A., 19-05-70, L41; C31484, PEMBERTON HQ58 WARREN NATIONAL PARK, -34 4167°S 115 9167°E, SPRINGETT, J. A , 19-05-70; C31485, PEMBERTON-VASSE, -34.4500°S 116 0333°E, SPRINGETT, J. A., 23-09-71, B10; C31486, TORBAY HEAD COTTAGE SITE BECK'S PLACE, -35 1333°S 117.6350°E, MAIN, B. Y., 19-02-83, P1; C31487, VALLEY OF THE GIANTS LARGE TINGLE TREE PICNIC AREA, -35.0000°S 116 8667°E, FRIEND, J. A., 11-06-81, L41; C31488, DEEPDENE HALF MILE NORTH, -34 2667°S 115.0833°E, PATERSON, A., 10-07-71, L41; C31489, FRANKLAND RIVER, -35 0000°S 116 8167°E, NICHOLLS COLLECTION, 02-12-25, G30; C31490, PEMBERTON NR EASTBROOK, -34 4000°S 116.1000°E, BISCOE, M. T , 05-01-61, G30; C31491, LAKE YEAGARUP 2 KM NE RITTER ROAD, -34 5167°S 115.8833°E, HARVEY, M. S. & WALDOCK, J. M., 02-05-90, B10, C31492, WARREN RIVER NATIONAL PARK, -34 5070°S 115 9833°E, HARVEY, M. S. & WALDOCK, J. M., 03-05-90, B10, C31493, WEST CAPE HOWE NATIONAL PARK, S OF TORBAY HILL NR SOUTH ROAD, -35.0833°S 117.6333°E, HARVEY, M. S. & WALDOCK, J. M., 27-03-93, B10; C31494, TORBAY HEAD LOT 40, -35.0833°S 117.6333°E, MAIN, B. Y., 21 09-87, P1, C31495, TORBAY HEAD LOT 40, -35 0833°S 117 6333°E, MAIN, B. Y., 03-01-85, P1; C31496, TORBAY HEAD, PIPE TRACK, -35 0833°S 117 6333°E, MAIN, B. Y., 15-10-84; C31497, NORNALUP, -35 0000°S 116 8167°E, NICHOLLS COLLECTION, 21-11-25, G30; C31498, FLINDERS BAY, -34 3167°S 115.1800°E, NICHOLLS COLLECTION, ??-??-33; C31499, NORNALUP FRANKLAND RIVER, -35 0000°S 116 8167°E, NICHOLLS COLLECTION, 11-01-33; C31500, FRANKLAND RIVER, -35.0000°S 116 8167°E, NICHOLLS COLLECTION, 11-01-33; C31501, FRANKLAND RIVER, -35.0000°S 116.8167°E, NICHOLLS COLLECTION, 02-12-25, G10; C31502, SWARBRICK'S TRACK VIA ALBANY, -35.0000°S 116.8167°E, NICHOLLS COLLECTION, 03-01-33, G30, C31503, TORBAY HEAD LOT 40, -35.0833°S 117.6333°E, MAIN, B Y., 21-04-84, P1; C31504, WALPOLE PENINSULAR, -34 9833°S 116.7167°E, NICHOLLS COLLECTION, 06-01-33; C31505, WALPOLE CAMP SITE, -34 9833°S 116 7167°E, NICHOLLS COLLECTION, 12-01-33,

C31506, FRANKLAND RIVER, -35.0000°S 116.8167°E, COLLECTOR UNKNOWN, ??-??-??, G30; C31507, PEMBERTON EASTBROOK, -34.4000°S 116.1000°E, MAIN, B. Y., 21-08-56; C31508, TORBAY HEAD, -35.1333°S 117.6350°E, MAIN, B. Y., 05-03-83, P1; C31509, TORBAY HEAD, -35.1333°S 117.6350°E, MAIN, B. Y., 17-06-83, P1, C31510/11, CAPE LEEUWIN FRESHWATER SWAMP, -34.3667°S 115.1333°E, SLACK-SMITH, S., 09-11-97; C31512, LAND LEACH GULLY ROAD TO WALPOLE?, -34.9833°S 116.7167°E, NICHOLLS COLLECTION, 25-11-39; C31513, WALPOLE ROAD TO WALPOLE NEAR LAND LEACH GULLY, -34.9833°S 118.7167°E, NICHOLLS COLLECTION, 23-11-38; C31514/6, WALPOLE NORNALUP NATIONAL PARK, -34.9833°S 116.7167°E, WALLIS, N., ??-??-91; C31517, DENMARK, -34.9500°S 117.3500°E, MCMILLAN, R. P., 20-01-97, L10; C31518, KARRI VALLEY RESORT, -34.4333°S 115.8500°E, HARVEY, M. S., 18-08-97, C31519, CAREY BROOK AT VASSE HIGHWAY, -34.4161°S 115.8100°E, HARVEY, M. S., 18-08-97, B10, C31520, WALPOLE NORNALUP NATIONAL PARK KARRI FOREST, -35.0000°S 116.7167°E, VAN HEURCK, P. ET AL., 13-05-97, L40, C31521, WALPOLE NORNALUP NATIONAL PARK TINGLE CREEK FOREST, -34.9917°S 116.6583°E, VAN HEURCK, P. ET AL., 20-05-97, B40; C31522, WALPOLE NORNALUP NATIONAL PARK TINGLE CREEK FOREST, -34.9917°S 116.6583°E, VAN HEURCK, P. ET AL., 20-05-97, L40, C31523, WALPOLE NORNALUP NATIONAL PARK TINGLE CREEK FOREST, -34.9583°S 116.8000°E, VAN HEURCK, P. ET AL., 14-05-97, B40; C31524, WALPOLE NORNALUP NATIONAL PARK TINGLE CREEK FOREST, -34.9583°S 116.8000°E, VAN HEURCK, P. ET AL., 14-05-97, L40, C31525, WALPOLE NORNALUP NATIONAL PARK TINGLE UPLAND FOREST, -34.9750°S 116.7917°E, VAN HEURCK, P. ET AL., 15-05-97, L40; C31526, WALPOLE NORNALUP NATIONAL PARK TINGLE UPLAND FOREST, -34.9750°S 116.7917°E, VAN HEURCK, P. ET AL., 15-05-97, G30, C31527, WALPOLE NORNALUP NATIONAL PARK TINGLE CREEK FOREST, -34.9750°S 116.7917°E, VAN HEURCK, P. ET AL., 14-05-97, B40; C31528, WALPOLE NORNALUP NATIONAL PARK TINGLE CREEK FOREST, -34.9750°S 116.7917°E, VAN HEURCK, P. ET AL., 14-05-97, G30, C31529, CAPE LEEUWIN SWAMP WEST EDGE OF SWAM AT BASE OF RISE, -34.3667°S 115.1333°E, SLACK-SMITH, S. ET AL., 19-08-00, S1; C31530, CAPE LEEUWIN SWAMP SOUTH SIDE OF SWAMP NEAR AND AT BASE OF SLOPE, -34.3667°S 115.1333°E, SLACK-SMITH, S. ET AL., 19-08-00, L10; C31531, CAPE LEEUWIN SWAMP SOUTHEAST CORNER OF WATER AUTHORITY COMPOUND, -34.3667°S 115.1333°E, SLACK-SMITH, S. ET AL., 19-08-00, S1; C31532, CAPE LEEUWIN SWAMP ADJACENT TO SOUTH FENCE OF WAWA, -34.3667°S 115.1333°E, SLACK-SMITH, S. ET AL., 19-08-00, L90; C31533, CAPE LEEUWIN SWAMP NEAR SOUTHERN FENCE OF WAWA COMPOUND, -34.3667°S 115.1333°E, SLACK-SMITH, S. ET AL., 20-08-00, S1; C31534, NORNALUP, -35.0000°S 116.8167°E, DOUGLAS, A. M., 18-07-82; C31535, MOONDYNE CAVE NEAR AUGUSTA, -34.2670°S 115.0830°E, LOWRY, J., 15-04-78.

Diagnosis: Habitus roller. Dorsal surface of head with long spines. Centre of frontal ridge forming obtuse triangular point without modification. Pereonites with long spines. Pereonal and pleonal epimera all with terminal spines.

Remarks: The length of the dorsal spines of this species varies throughout the range of this species. It may be a clinal feature associated within rainfall or it may be indicating the presence of at least four different species.

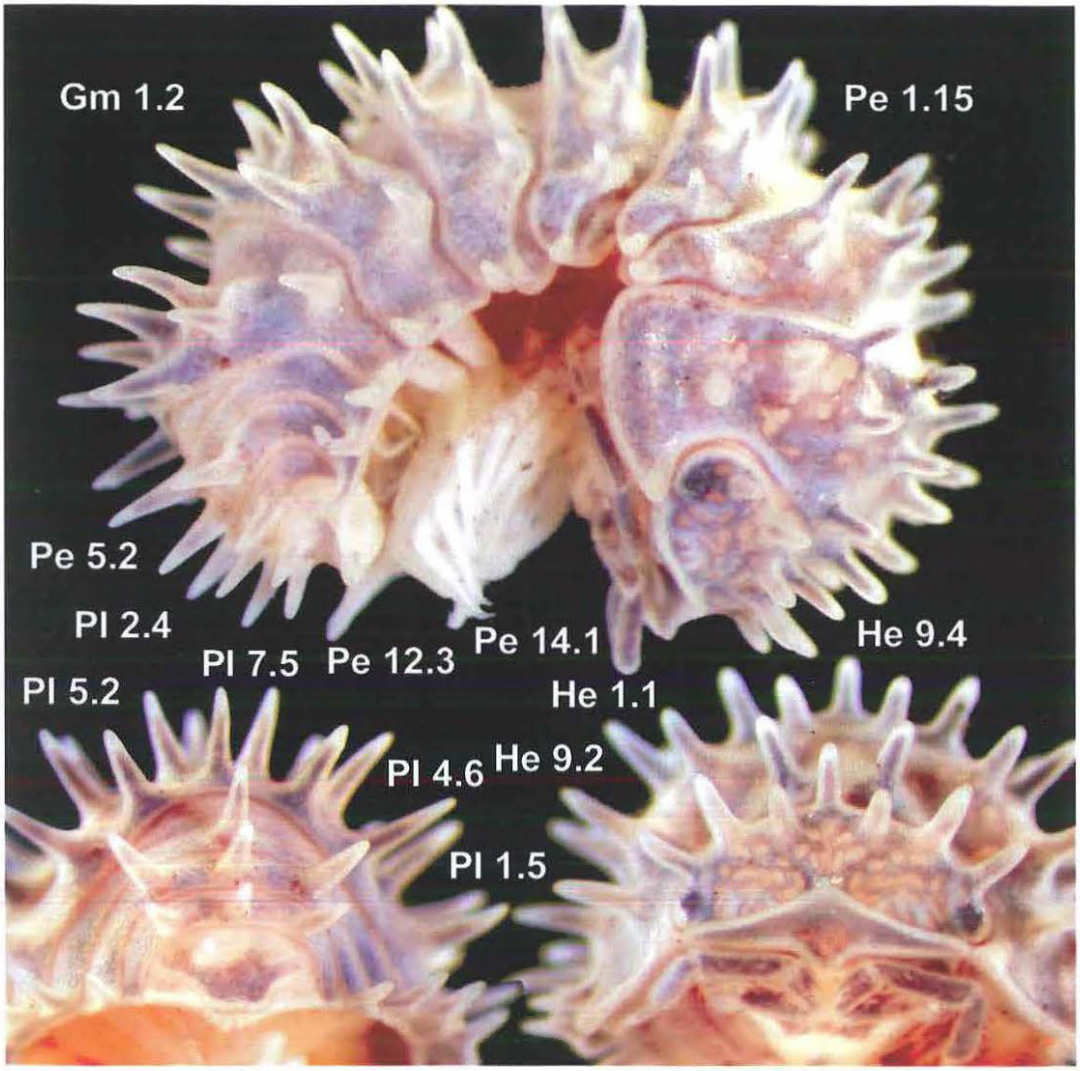


Plate 3.77. <u>Pseudolaureola</u> <u>wilsmorei</u> **from Warren National Park (C30550) (length 4 mm).**

3.17.2.4. Pseudolaureola new species 3

Plate 3 17, Pe 1.16; Plate 3.30, Pe 14.1; Plate 3.78.

Pseudolaureola sp. 2 Judd & Horwitz, 2003

MATERIAL EXAMINED: C30575, WARREN NATIONAL PARK, PETTICOAT LANE, -34.5070°S 115.9130°E, JUDD, S., 13-08-98, B10; C30576, WARREN NATIONAL PARK, PETTICOAT LANE, -34 5070°S 115.9130°E, JUDD, S., 13-08-98, L20; C30577, SHANNON NATIONAL PARK (FISH CREEK ROAD), -34.6250°S 116.4370°E, JUDD, S., 27-01-99, L10; C30578, SHANNON NATIONAL PARK (FISH CREEK ROAD), -34.6250°S 116.4370°E, JUDD, S., 27-01-99, L20; C30579, BOMBAKUP STATE FOREST, -34 6080°S 116 0320°E, JUDD, S., 28-01-99, L10, C31540, SHANNON NATIONAL PARK DOG POOL ON SHANNON RIVER, -34.7667°S 116 3667°E, HARVEY, M S. & WALDOCK, J. M., 30-04-90, P3, C31541, SHANNON NATIONAL PARK DOG POOL ON SHANNON RIVER, -34 7667°S 116.3667°E, WALDOCK, J. M & SAMPEY, A., 09-06-93, L20; C31542, SHANNON NATIONAL PARK DOG POOL ON SHANNON RIVER, -34.7667°S 116 3667°E, HARVEY, M. S. & WALDOCK, J M., 30-04-90; C31543, PEMBERTON EASTBROOK, -34.4000°S 116.1000°E, MAIN, B Y., 21-08-56; C31544, KARRI VALLEY RESORT, -34.4333°S 115 8500°E, HARVEY, M. S., 18-08-97.

Diagnosis: Habitus roller. Head bumpy. Pereonites with prominent spherical bumps producing fine setae. Pereonal and pleonal epimera all without terminal spines.

Remarks: This species is included in Pseudolaureola rather than Pseudodiploexochus because it is larger than the usual size of the latter genus (max. 4 mm, Taiti & Ferrara, 1979) and because the arrangement of bumps matches those of the spines in P. wilsmorei and other Pseudolaureola from the region. However, the form of the pereonal epimera and lack of spines would exclude it from the genus sensu Dalens (1998).

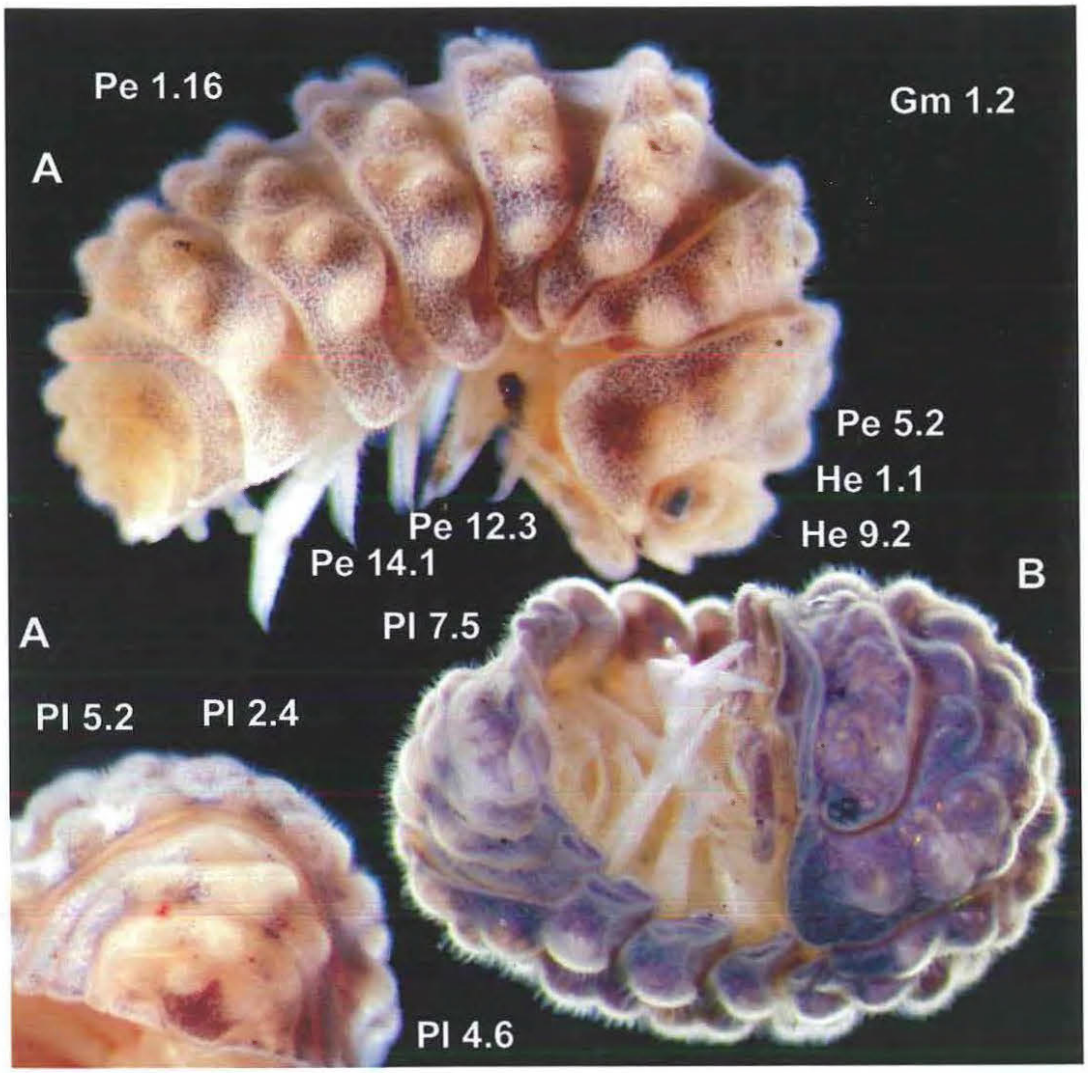


Plate 3.78. <u>Pseudolaureola</u> **species 3 from (A) Shannon National Park (C30578) (length 4.5 mm) and (B) Bombakup State Forest (C30579) (length 4 mm).**

3.17.2.5. Pseudolaureola new species 4

Plate 3.17, Pe 1.17; Plate 3.21, Pe 5.3; Plate 3.79.

MATERIAL EXAMINED: C30571, WAYCHINICUP NATIONAL PARK, -34.8800°S 118.3270°E, JUDD, S., 19-12-98, G20.

Diagnosis: Habitus roller. Head with very short spines. Pereonites with medium length spines and row of spines nearest to lateral border of pereonal epimera widened and paddle shaped. Pereonal and pleonal epimera all without terminal spines.

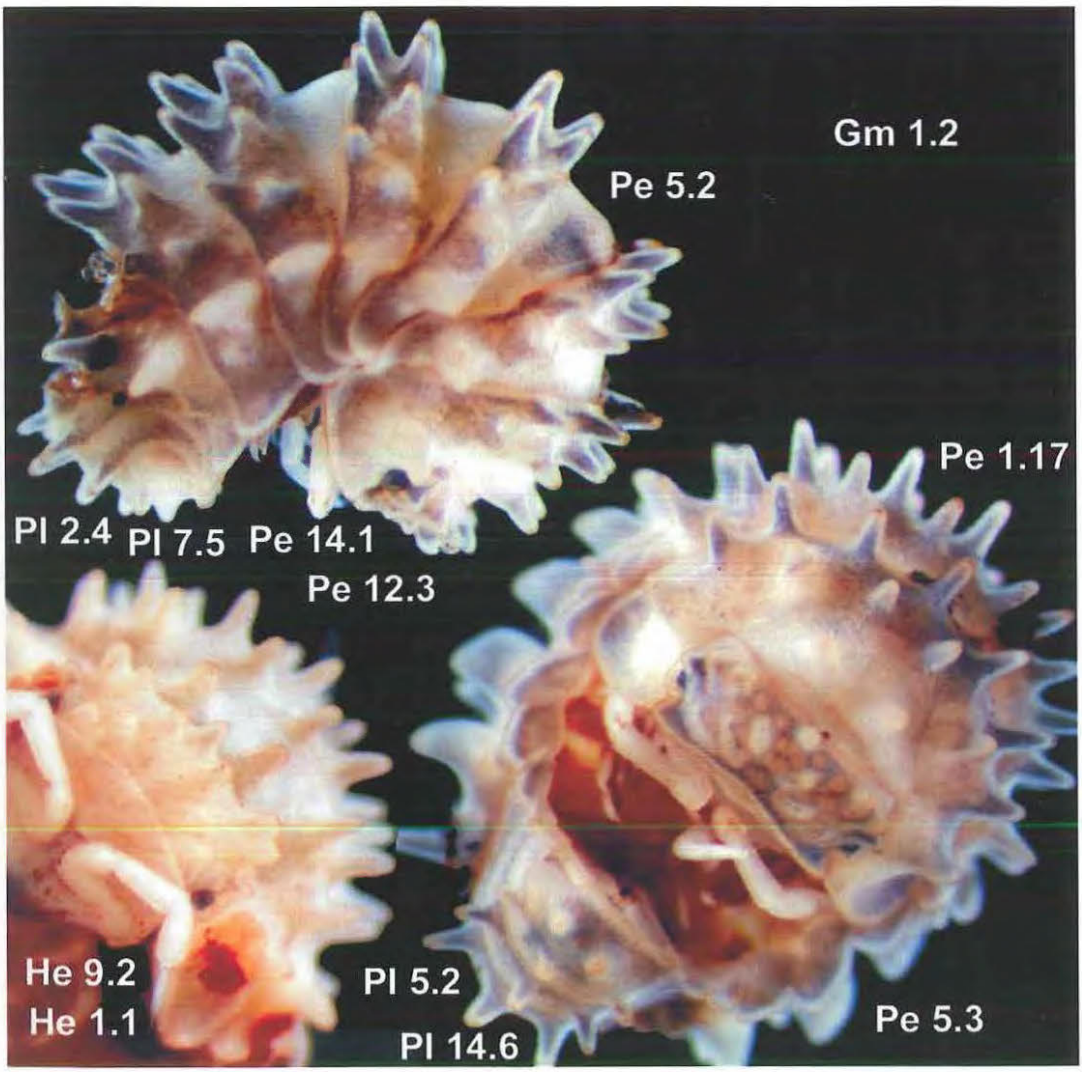


Plate 3.79. Pseudolaureola species 4 from Waychinicup National Park (C30571) (length 3.5 mm).

3.17.2.6. Pseudolaureola new species 5

Plate 3.9, He 5.4; Plate 3.19. Pe 3.1; Plate 3.21, Pe 5.2; Plate 3.80

Pseudolaureola sp. 3 Judd & Horwitz, 2003

MATERIAL EXAMINED: C30572, PRESTON CONSERVATION PARK, -33.6030°S 116.0630°E, JUDD, S., 24-11-98, G30; C30573, BRIDGETOWN WEST NATURE RESERVE, -33.9520°S 116.0780°E, JUDD, S., 01-12-98, L10; C30574, ELLIS CREEK ROAD, -33.9350°S 115.8820°E, JUDD, S., 03-12-98, L10; C31539, WELLINGTON MILL, -33.4500°S 115.9000°E, HARVEY, M. S., 10-05-97.

Diagnosis: Habitus roller. Head bumpy or sculptured in appearance. Pereonites with very short blunt spines almost bumps. Row nearest to the lateral border of the pereonal epimera slightly widened. Pereonal and pleonal epimera all without terminal spines.

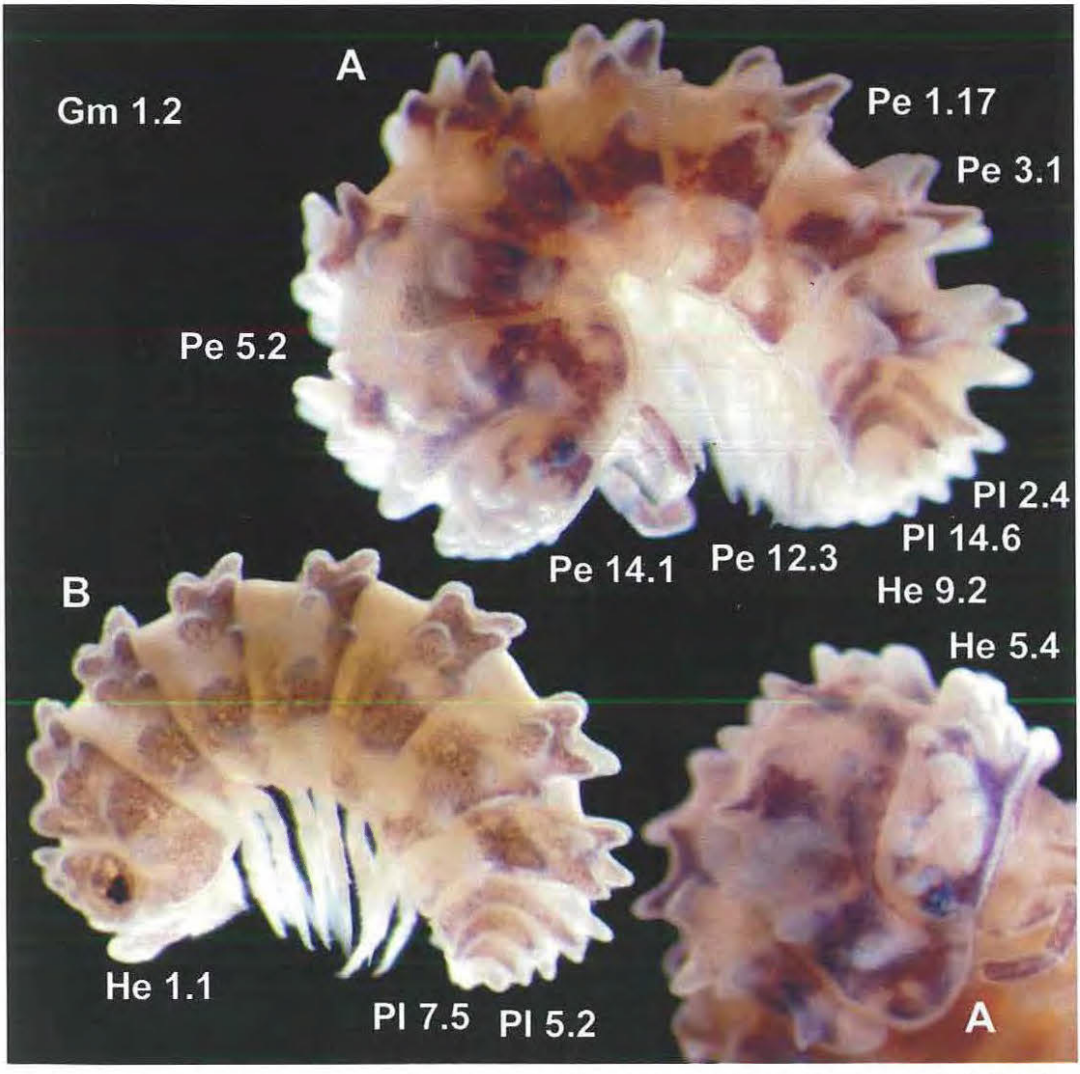


Plate 3.80. Pseudolaureola species 5 from (A) jarrah forest at Ellis Creek Road (C30574) (length 2.5 mm) and (B) Preston Conservation Park (C30572) (length 2 mm).

3.17.3. GENUS SPHERILLO DANA

Diagnosis: The following diagnosis is abbreviated from Green (1961, p. 357): Dorsal surface of animal never with spines. Second antenna slender with greater part of it protruding from head. Posterior borders of pereonal segments 1-4 either not incurved or only slightly incurved on each side. Conspicuous inner lobe on the lateral border of pereonal epimeron 1 continuous with lateral border of epimeron. Lobes only present on ventral surface of pereonal epimera 1 and 2. Lobe on epimera 2 may be connected to or separated from epimeral border. Exopodites of pleopods all with pleopodal lungs. Pleopods occupy considerably more than one-third width of pleon. Telson not keeled. Breadth of protopodite of uropod, if greater than the length of the protopodite, is not more than 1.25 times the latter. Inner border of protopodite incurved but not angularly indented near insertion of protopodite.

Remarks: In the species described here, inner lobe of the first pereonal epimeron extends as far as (Spherillo sp. 3), or further than (all other spp.) the posterior margin of epimeron 1.

3.17.3.1. Spherillo species 1

Plate 3.2, Gm 2.1, Plate 3.8, He 4.7; Plate 3.26, Pe 10.3; Plate 3.81.

MATERIAL EXAMINED: C30594, CANNING RIVER (BELOW CANNING DAM), -32.1430°S 116 1100°E, JUDD, S., 25-08-98, G30.

Diagnosis: Habitus roller. Highly convex. Pale in colour, almost white. Pereonal epimeron 1 with ventral groove (sulcus marginali). Eye very small, less than 6 ocelli. Frontal ridge very flat against dorsal surface of head. Posterior margin of pereonal epimeron 1 almost straight. Telson very wide and barely wider at distal margin than at midpoint.

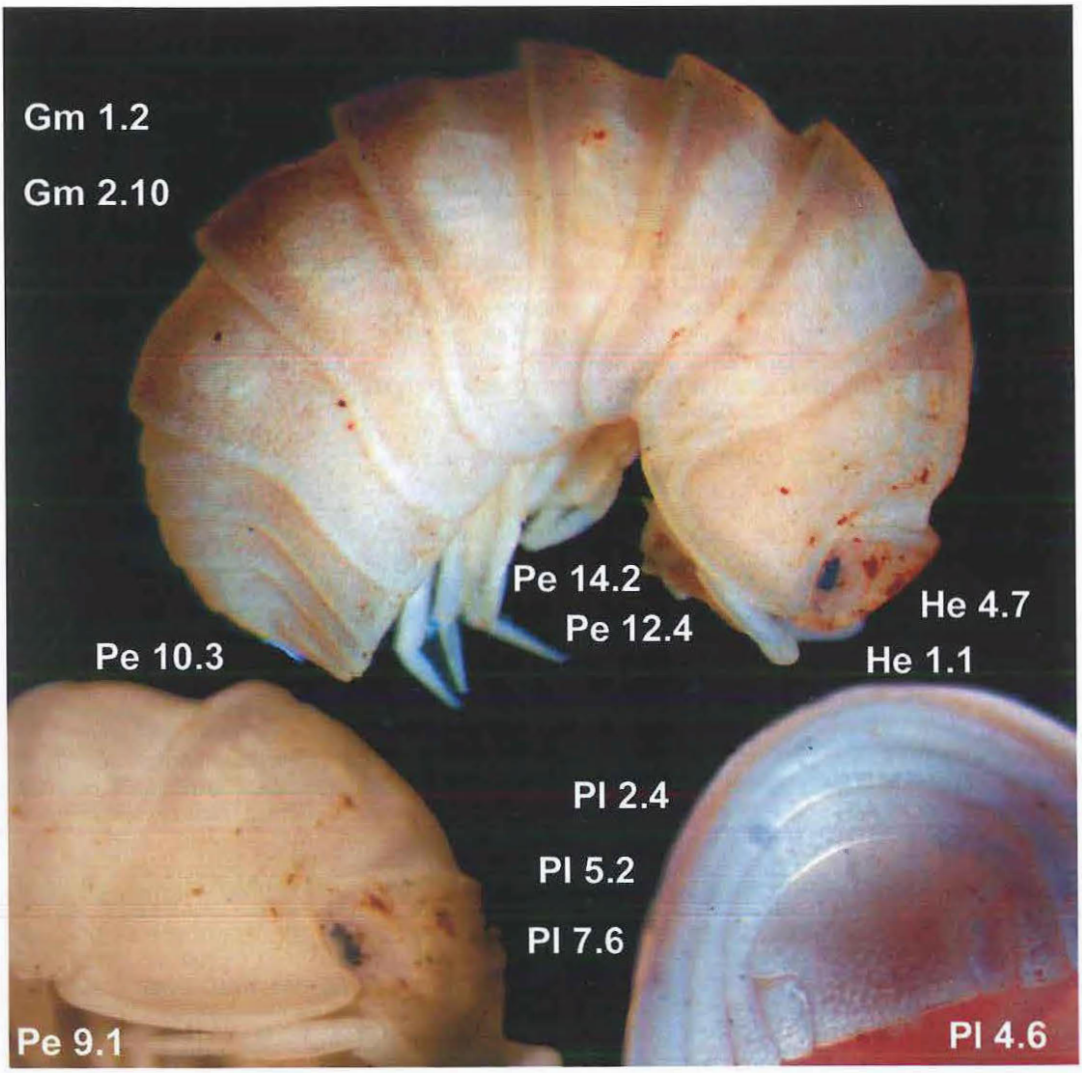


Plate 3.81. Spherillo species 1 from jarrah forest adjacent to the Canning River, near Canning Dam (C30594) (length 4 mm).

3.17.3.2. Spherillo species 2

Plate 3.8, He 4.8; Plate 3.17, Pe 1.20; Plate 3.25, Pe 9.1; Plate 3.29, Pe 13.1; Plate 3.31, Pe 15.1; Plate 3.82a, 3.82b, 3.82c.

Armadillidae sp. 6 Judd & Horwitz, 2003

MATERIAL EXAMINED. C30595, BUNDARRA NATURE RESERVE, -30 9250°S 115 8250°E, JUDD, S , 04-10-98, R2, C30596/7, BUNDARRA NATURE RESERVE, -30.9250°S 115.8250°E, JUDD, S., 04-10-98, L41, C30598, BUNDARRA NATURE RESERVE, -30 9250°S 115 8250°E, JUDD, S , 04-10-98, G30; C30599/600, WEDGE ISLAND DUNE, -30 8410°S 115.2320°E, JUDD, S., 07-08-98, L10; C30601, CHITTERING LAKE RESERVE, -31 4180°S 116 0930°E, JUDD, S., 08-08-98, B40; C30602, CHITTERING LAKE RESERVE, -31.4180°S 116.0930°E, JUDD, S., 08-08-98, B30; C30603, JOHN FOREST NATIONAL PARK JANE BROOK, -31.8850°S 116 0900°E, JUDD, S., 11-08-98, R1, C30604, JAM HILL NATURE RESERVE, -30 6860°S 115.8020°E, JUDD, S , 02-10-98, L10; C30605, MOGANMOGANNING NATURE RESERVE, -31.1200°S 116.2530°E, JUDD, S., 11-10-98, G40; C30606, MOGANMOGANNING NATURE RESERVE, -31.1200°S 116.2530°E, JUDD, S , 11-10-98, L10, C30607, MOGANMOGANNING NATURE RESERVE, -31.1200°S 116.2530°E, JUDD, S., 11-10-98, G30; C30608, MOOLIABEENEE ROAD (C42743), -31.3480°S 115.9950°E, JUDD, S., 18-10-98, R3; C30609, MOUNT DALE, -32 0918°S 116.2779°E, WATSON, A., 01-10-01, P3; C30610, MOUNT DALE, -32.0940°S 116 2804°E, WATSON, A., 01-10-01, P3; C30611/15, MOUNT DALE, -32.0885°S 116.2810°E, WATSON, A., 01-10-01, P3; C30616, MOUNT DALE, -32.0869°S 116.2928°E, WATSON, A., 01-10-01, P3, C31556, ARMADALE, -32.1500°S 116.0000°E, COLLECTOR UNKNOWN, 08-08-32; C31557, DARLINGTON NR PERTH, -31.9167°S 116 0667°E, COLLECTOR UNKNOWN, 19-04-32; C31558, GNANGARA, PINUS PINASTER PLANTATION, -31.7333°S 115 8333°E, SPRINGETT, J. A., 77-03-70, P1; C31559, CARDUP, -32.2672°S 116.0011°E, DELL, J , 05-12-96, P2; C31560, MARANGAROO RESERVE RICHENDA COURT SITE, -31.8333°S 115.8333°E, WALDOCK, J. M., 27-09-97, P3; C31991, WARWICK OPEN SPACE, -31.8428°S 115.8139°E, HARVEY, M. S. & WALDOCK, J. M., 28-11-95, P3; C31992, WARWICK OPEN SPACE, -31.8425°S 115.8167°E, HARVEY, M. S. & WALDOCK, J M , 28-03-96, P3; C31993, WARWICK OPEN SPACE, -31 8428°S 115.8139°E, HARVEY, M. S. & WALDOCK, J. M., 25-09-95, P3; C31994, WARWICK OPEN SPACE, -31.8425°S 115.8167°E, HARVEY, M. S. & WALDOCK, J. M., 29-01-96, P3; C31995, WARWICK OPEN SPACE, -31.8425°S 115 8167°E, HARVEY, M S & WALDOCK, J. M , 28-11-95, P3, C31996, LANDSDALE SCHOOL, -31.8206°S 115.8503°E, HARVEY, M. S & WALDOCK, J. M., 29-01-96, P3, C31997, LANDSDALE SCHOOL, -31.8206°S 115 8503°E, WALDOCK, J M., WEST, P. L. & WHEELER, A., 28-03-96, P3, C31998, LANDSDALE SCHOOL, -31.8206°S 115.8503°E, HARVEY, M. S & WALDOCK, J. M., 25-09-95, P3; C31999, TUART HILL, -31.8806°S 115.8589°E, WALDOCK, J. M. ET AL., 18-11-93, P3; C32000, TUART HILL, -31 8803°S 115.8583°E, HARVEY, M. S. & WALDOCK, J. M., 20-07-93, P3, C32001, TUART HILL, -31.8806°S 115 8594°E, WALDOCK, J M. ET AL., 18-11-93, P3; C32002, TUART HILL, -31.8803°S 115.8583°E, WALDOCK, J. M. ET AL., 18-11-93, P3; C32003, TUART HILL, -31.8806°S 115.8594°E, HARVEY, M. S. & WALDOCK, J M , 20-07-93, P3; C32004, TUART HILL, -31.8806°S 115.8594°E, WALDOCK, J. M., SAMPEY, A. & THORPE, A., 23-09-93, P3; C32005, TUART HILL, -31.8806°S 115 8589°E, HARVEY, M. S. & WALDOCK, J M., 21-03-94, P3; C32006, TUART HILL, -31.8806°S 115 8589°E, HARVEY, M. S. & WALDOCK, J M., 20-07-93, P3; C32007, TUART HILL, -31.8803°S 115 8583°E, HARVEY, M S. & WALDOCK, J. M., 21-03-94, P3; C32008, TUART HILL, -31.8806°S 115.8594°E, HARVEY, M S. & WALDOCK, J. M., 19-05-94, P3; C32009, MARANGAROO RESERVE, -31 8308°S 115.8342°E, HARVEY, M. S. & WALDOCK, J. M., 25-09-95, P3; C32010, MARANGAROO RESERVE, -31.8308°S 115.8342°E, DELL, J., 10-03-96, P2, C32011, MARANGAROO RESERVE, -31.8308°S 115 8342°E, HARVEY, M. S. & WALDOCK, J. M , 29-01-96, P3; C32012, MARANGAROO RESERVE, -31 8272°S 115.8344°E, WALDOCK, J. M , WEST, P. L. & WHEELER, A., 28-03-96, P3; C32013, MARANGAROO RESERVE, -31.8308°S 115.8342°E, WALDOCK, J. M , WEST, P. L. & WHEELER, A , 28-03-96, P3, C32014, MARANGAROO RESERVE, -31.8272°S 115 8344°E, HARVEY, M. S & WALDOCK, J M., 28-11-95, P3, C32015, MARANGAROO RESERVE, -31.8272°S 115.8344°E, HARVEY, M. S. & WALDOCK, J. M., 25-09-95, P3; C32016, MARANGAROO RESERVE, -31 8272°S 115.8344°E, HARVEY, M. S. & WALDOCK, J. M., 29-01-96, P3; C32017, MARANGAROO RESERVE, -31.8308°S 115.8342°E, HARVEY, M S. & WALDOCK, J M., 28-11-95, P3; C32018, MT HENRY, -32 0314°S 115.8622°E, HARVEY, M. S. & WALDOCK, J M., 14-01-95, P3; C32019, MT HENRY, -32 0328°S 115 8606°E, HARVEY, M. S & WALDOCK, J. M , 04-05-95, P3; C32020, TRIGG DUNE BUSH, -31.8692°S 115.7606°E, HARVEY, M S & WALDOCK, J. M., 25-09-95, P3; C32021, TRIGG DUNE BUSH, -31.8692°S 115.7606°E, HARVEY, M S. & WALDOCK, J M , 29-01-96, P3; C32022, TRIGG DUNE BUSH, -31 8792°S 115.7547°E, HARVEY, M S & WALDOCK, J. M., 28-11-95, P3; C32023, TRIGG DUNE BUSH, -31.8792°S 115.7547°E, HARVEY, M S. & WALDOCK, J. M , 29-01-96, P3; C32024, BOLD PARK, -31.9417°S 115.7742°E, WALDOCK, J. M , 24-09-93, P3; C32025, BOLD PARK, -31.9364°S 115.7639°E, WALDOCK, J. M. ET AL., 24-09-93, P3; C32026, BOLD PARK, -31.9353°S 115.7750°E, HARVEY, M. S & WALDOCK, J. M., 20-07-93, P3; C32027, BOLD PARK, -31.9425°S 115 7703°E, HARVEY, M. S. & WALDOCK, J. M., 20-07-93, P3; C32028, BOLD PARK, -31.9364°S 115.7639°E, WALDOCK, J M. ET AL., 18-11-93, P3; C32029, BOLD PARK, -31.9364°S 115 7639°E, WALDOCK, J. M , 06-01-94, P3; C32030, BOLD PARK, -31 9364°S 115 7639°E, WALDOCK, J M , 06-01-94, P3; C32031, BRICKWOOD RESERVE, CARDUP, -32 2339°S 116 0019°E, WALDOCK, J M., WEST, P. L. & LONGBOTTOM, A., 17-06-96, P3, C32032, BRICKWOOD RESERVE, CARDUP, -32.2333°S 116 0006°E, WALDOCK, J. M., WEST, P L. & LONGBOTTOM, A , 17-06-96, P3, C32033, BRICKWOOD RESERVE, CARDUP, -32.2311°S 116 0033°E WALDOCK, J. M., WEST, P. L. & LONGBOTTOM, A., 17-06-96, P3; C32034, RUSHTON ROAD, -32 0039°S 116.0189°E, WALDOCK, J. M., WEST, P L & LONGBOTTOM, A , 17-06-96, P3; C32035, RUSHTON ROAD, -32 0639°S 116.0189°E, WALDOCK, J M , WEST, P. L & LONGBOTTOM, A., 17-06-96, P3, C32036, BUSHMEAD, -31.9197°S 116.0169°E, WALDOCK, J. M., WEST, P. L. & LONGBOTTOM, A., 17-06-96, P3; C32037, HARTFIELD PARK, -32.0000°S 115 9953°E, WALDOCK, J M., WEST, P L & LONGBOTTOM, A., 17-06-96, P3, C32038, HARTFIELD PARK, -31.9978°S 115.9944°E,

WALDOCK, J. M., WEST, P. L. & LONGBOTTOM, A., 17-06-96, P3, C32039, JANDAKOT AIRPORT, -32 0919°S 115 8744°E, WALDOCK, J M & HARVEY, M S, 19-01-95, P3, C32040, JANDAKOT AIRPORT, -32.0919°S 115 8744°E, WALDOCK, J. M. & LONGBOTTOM, A. F., 04-11-94, P3, C32041, JANDAKOT AIRPORT, -32 0919°S 115.8744°E, WALDOCK, J. M. & HARVEY, M. S., 06-07-95, P3; C32042, JANDAKOT AIRPORT, -32 0919°S 115.8744°E, WALDOCK, J. M. & HARVEY, M S., 04-05-95, P3; C32043, JANDAKOT AIRPORT, -32.0933°S 115 8775°E, WALDOCK, J M. & HARVEY, M. S., 21-03-95, P3; C32044, HEPBURN HEIGHTS, -31 8172°S 115.7703°E, WALDOCK, J. M. & HARVEY, M S., 28-11-95, P3; C32045, HEPBURN HEIGHTS, -31 8172°S 115.7703°E, WALDOCK, J. M. & HARVEY, M S., 25-09-95, P3; C32046, HEPBURN HEIGHTS, -31 8172°S 115.7703°E, WALDOCK, J M & HARVEY, M S., 29-01-96, P3, C32047, HEPBURN HEIGHTS, -31.8172°S 115 7703°E, WALDOCK, J. M., WEST, P. L. & WHEELER, A., 28-03-96, P3; C32048, HEPBURN HEIGHTS, -31.8186°S 115 7697°E, WALDOCK, J. M. & HARVEY, M. S., 28-11-95, P3; C32049, HEPBURN HEIGHTS, -31.8158°S 115 7781°E, WALDOCK, J. M. & HARVEY, M. S., 28-11-95, P3; C32050, HEPBURN HEIGHTS, -31.8158°S 115 7781°E, WALDOCK, J M. & HARVEY, M. S., 25-09-95, P3, C32051, HEPBURN HEIGHTS, -31.8183°S 115 7672°E, WALDOCK, J M & HARVEY, M S., 28-11-95, P3, C32052, NORMAN ROAD, CARDUP, -32 2672°S 116.0122°E, WALDOCK, J. M., WEST, P L. & LONGBOTTOM, A., 17-06-96, P3; C32053, CARDUP RESERVE, -32.2431°S 115 9856°E, WALDOCK, J. M., WEST, P. L. & LONGBOTTOM, A., 17-06-96, P3, C32054, CARDUP RESERVE, -32.2444°S 115.9875°E, WALDOCK, J M., WEST, P L. & LONGBOTTOM, A., 17-06-96, P3; C32055, CARDUP RESERVE, -32.2481°S 115 9856°E, WALDOCK, J. M., WEST, P. L. & LONGBOTTOM, A., 17-06-96, P3; C32056, PERTH AIRPORT, -31 9767°S 115.9744°E, WALDOCK, J. M. ET AL., 16-11-93, P3; C32057, PERTH AIRPORT, -31 9767°S 115.9744°E, WALDOCK, J. M., GOODSELL, J & WEBB, J., 06-01-94, P3; C32058, PERTH AIRPORT, -31 9761°S 115.9736°E, WALDOCK, J. M. ET AL., 24-06-93, P3; C32059, PERTH AIRPORT, -31.9761°S 115.9736°E, WALDOCK, J. M. & HARVEY, M. S., 19-05-94, P3; C32060, PERTH AIRPORT, -31.9761°S 115 9736°E, WALDOCK, J. M ET AL., 23-09-93, P3; C32061, PERTH AIRPORT, -31 9681°S 115.9681°E, WALDOCK, J. M. & HARVEY, M. S., 19-05-94, P3; C32062, PERTH AIRPORT, -31.9681°S 115.9681°E, WALDOCK, J. M. ET AL., 23-09-93, P3; C32063, PERTH AIRPORT, -31.9681°S 115 9681°E, WALDOCK, J. M ET AL., 18-11-93, P3, C32064, PERTH AIRPORT, -31 9681°S 115.9681°E, WALDOCK, J. M. ET AL., 24-08-93, P3; C32065, PERTH AIRPORT, -31 9675°S 115 9697°E, WALDOCK, J. M. & HARVEY, M. S., 19-05-94, P3, C32066, PERTH AIRPORT, -31 9675°S 115 9697°E, WALDOCK, J. M. & HARVEY, M. S., 18-03-94, P3, C32067, TALBOT ROAD RESERVE, -31.8733°S 116.0478°E, WALDOCK, J. M., 10-12-93, P3; C32068, TALBOT ROAD RESERVE, -31.8733°S 116.0478°E, WALDOCK, J. M. ET AL., 18-11-93, P3, C32069, TRIGG DUNE BUSH, -31.8692°S 115 7606°E, WALDOCK, J M. & HARVEY, M S., 28-11-95, P3.

Diagnosis: Habitus roller. Animal convex. Pereonal epimeron 1 with ventral groove (sulcus marginali) approximately same width along entire length. Eye well developed. Frontal ridge not raised from dorsal surface of head. Posterior margin of pereonal epimeron 1 produced backwards. Posterior lateral part of epimeron sub-equal or shorter in length to inner lobe, inner lobe being clearly visible in lateral view. Pereonal epimeron 2 pointed. Pereonites slightly bumpy to very bumpy (highly variable character state, consequently a number of different specimens are illustrated here) but, when apparent, bumps are in longitudinal rows. Posterior margin of pereonal epimera 5, 6 & 7 with posterior kink giving a highly characteristic shape. Telson wide and very short with narrowest point close to distal margin.

Remarks: The species illustrated here are likely to be a complex of two or more closely related species. There are obvious differences in the degree of bumps of the dorsal surface. Therefore, three forms are illustrated; a smooth form found et only one locality and two bumpy forms illustrating variation with the character state. Whilst the smooth form is most likely a different species, bumpy forms display large variation in the degree of bumps both within samples and between sites.

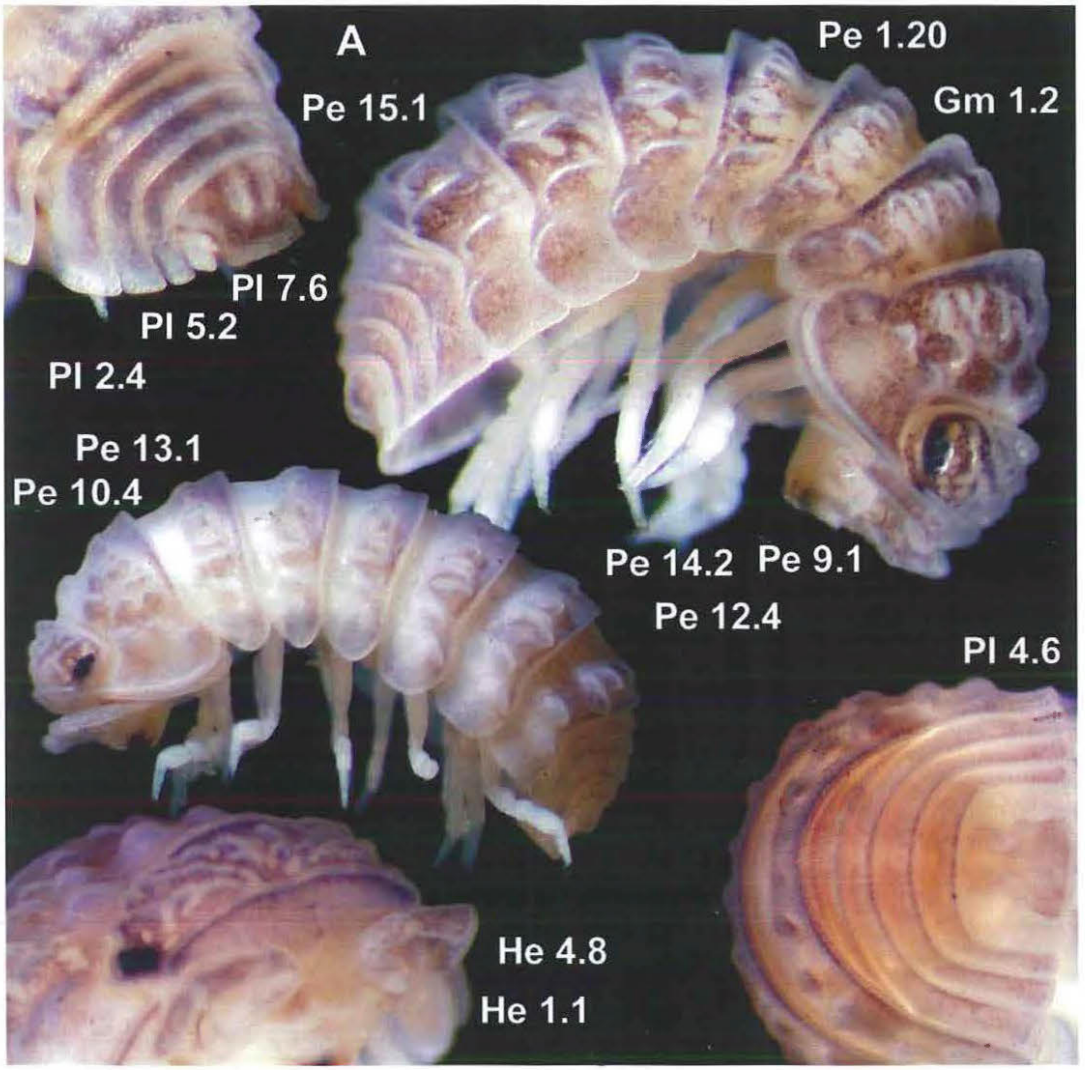


Plate 3.82a. Spherillo species 2 from Bundarra Nature Reserve (C30595) (length 5 mm).

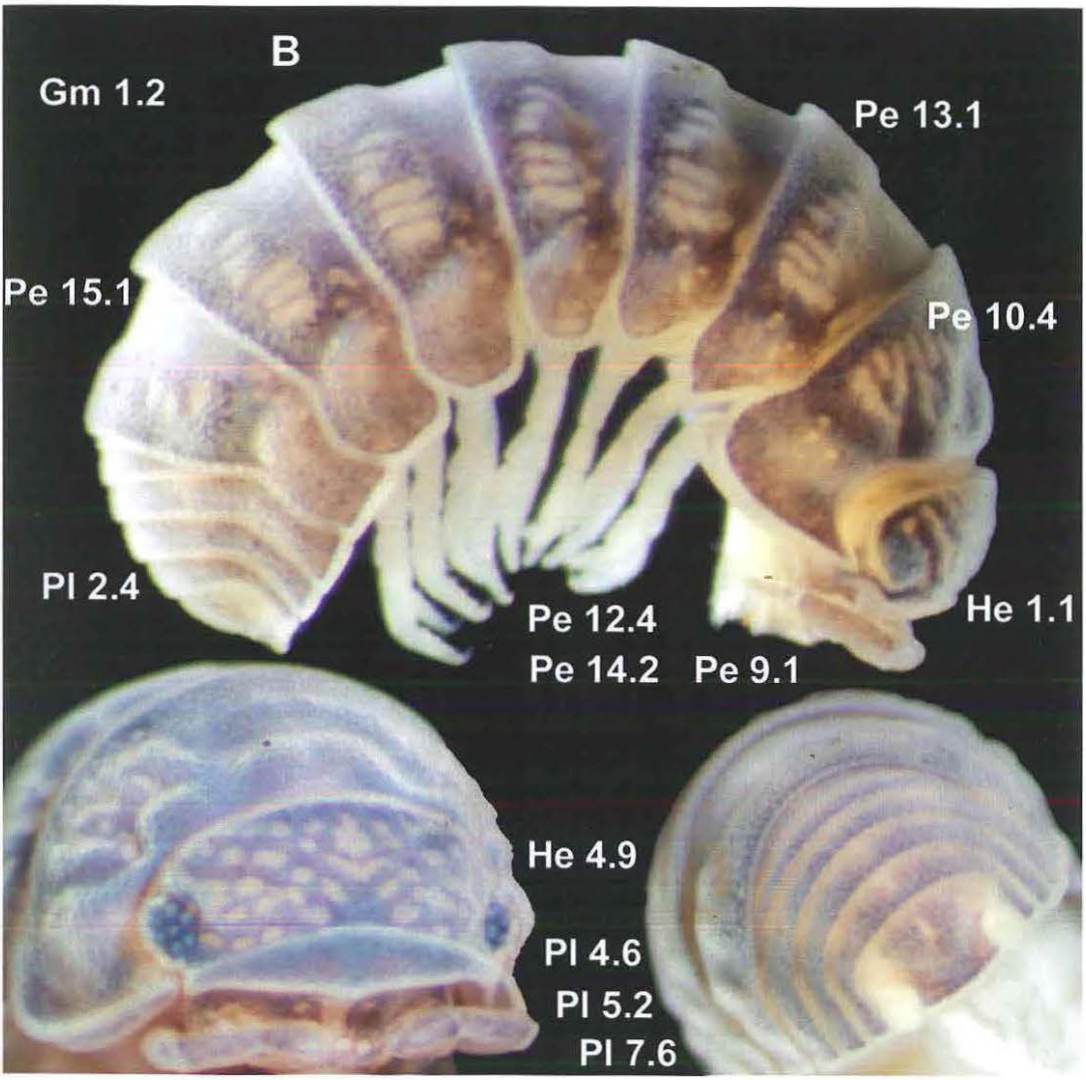


Plate 3.82b. Spherillo species 2 from Moganmoganning Nature Reserve (C30605) (length 3.5 mm).

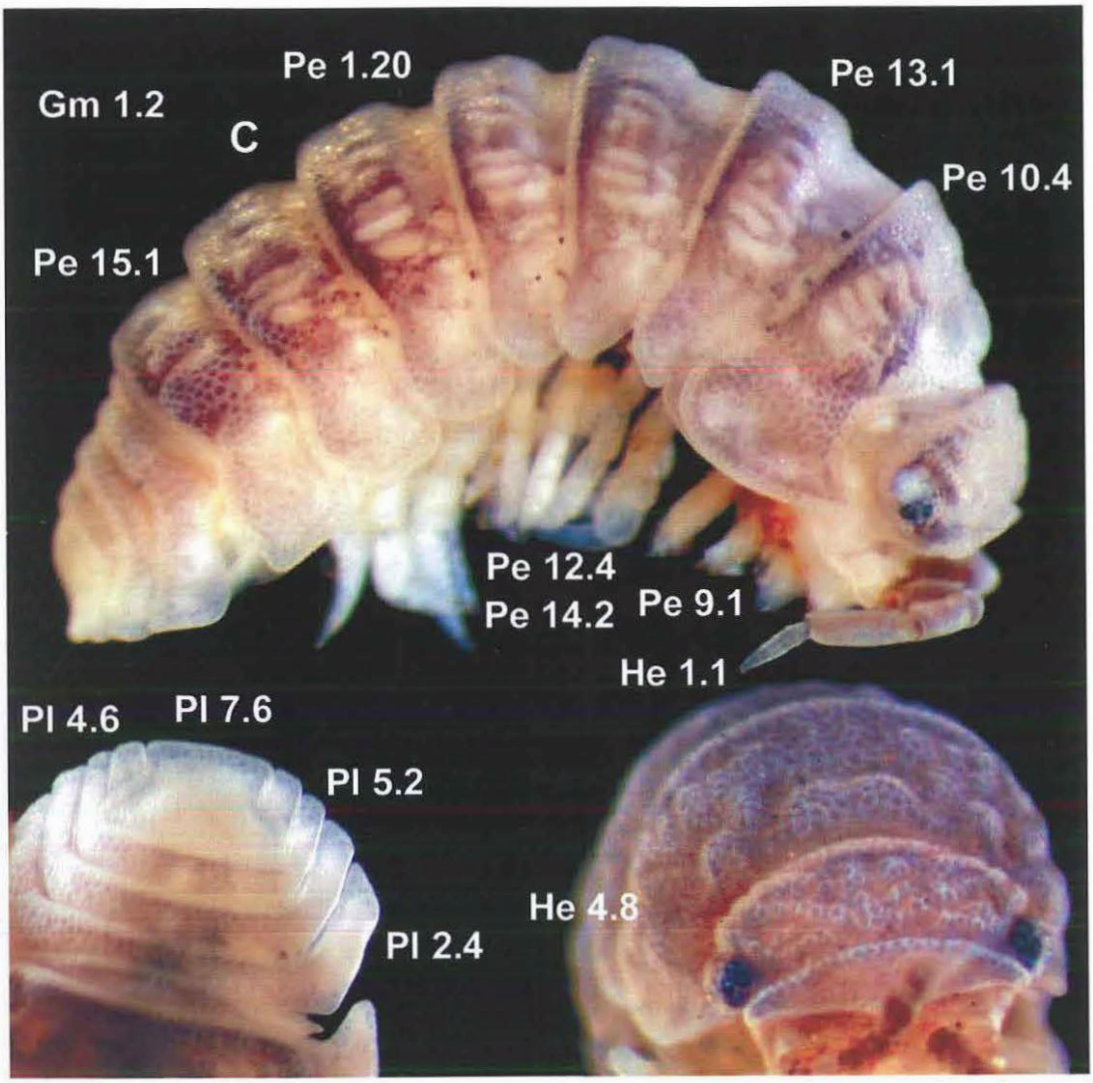


Plate 3.82c. Spherillo species 2 from Cardup Reserve (C32055) (length 4 mm).

3.17.3.4. Spherillo species 3

Plate 3.8, He 4.9; Plate 3.25, Pe 9.2; Plate 3.29, Pe 13.2; Plate 3.31, Pe 15.2; Plate 3.83.

Armadillidae sp. 4 Judd & Horwitz, 2003

MATERIAL EXAMINED C30582, RATE BLOCK, -34.8350°S 117 0070°E, JUDD, S., 01-09-99, L10; C30583, RATE BLOCK, -34 8350°S 117 0070°E, JUDD, S., 01-09-99, G30; C30584, RATE BLOCK, -34.8350°S 117 0070°E, JUDD, S., 01-09-99, L10. C30585, RATE BLOCK, -34 8350°S 117 0070°E, JUDD, S., 01-09-99, B10. C30586, RATE BLOCK, -34 8350°S 117 0070°E, JUDD, S., 01-09-99, L41; C30587, ORDNANCE STATE FOREST, -34 8680°S 116 6650°E, JUDD, S., 10-01-99, B10, C30588, ORDNANCE STATE FOREST, -34.8680°S 116.6650°E, JUDD, S., 10-01-99, L10, C30589, MOUNT FRANKLAND NATIONAL PARK CROSSING BLOCK, -34.8030°S 116 8830°E, JUDD, S., 10-01-99, G40; C30590, SHANNON NATIONAL PARK (FISH CREEK ROAD), -34 6250°S 116 4370°E, JUDD, S., 27-01-99, L10; C30591/2, SHANNON NATIONAL PARK (FISH CREEK ROAD), -34 6250°S 116 4370°E, JUDD, S., 27-01-99, B10, C30593, WEST CAPE HOWE NATIONAL PARK, -35 0620°S 117 6430°E, JUDD, S., 17-12-98, B10; C31546, NORNALUP, TINGLEWOOD?, -35 0000°S 116 8167°E, NICHOLLS COLLECTION, ??-??-??, B10; C31546, FRANKLAND RIVER, -35 0000°S 116 8167°E, NICHOLLS COLLECTION, 02-12-25, G30, C31547, LAKE YEAGARUP 2 KM NE RITTER ROAD, -34 5414°S 115 8750°E, HARVEY, M. S. & WALDOCK, J. M., 02-05-90, C31548, WARREN RIVER NATIONAL PARK, -34 5070°S 115 9833°E, HARVEY, M. S. & WALDOCK, J. M., 03-05-90, B10; C31549, THE CASCADES 8 KM SSW PEMBERTON, -34 5000°S 116 0000°E, HARVEY, M. S. & WALDOCK, J. M., 03-05-90, B10, C31550, PEMBERTON 4 KM NW, -34 4167°S 115.9500°E, HARVEY, M. S. & WALDOCK, J. M., 02-05-90, C31551, SHANNON NATIONAL PARK DOG POOL ON SHANNON RIVER, -34.7500°S 116.3667°E, HARVEY, M. S. & WALDOCK, J. M., 30-04-90, B10; C31552, WEST CAPE HOWE NATIONAL PARK, -35.1000°S 117 6167°E, HARVEY, M. S. & WALDOCK, J. M., 26-04-90, C31553, SHANNON NATIONAL PARK DOG POOL ON SHANNON RIVER, -34 7667°S 116.3667°E, HARVEY, M. S. & WALDOCK, J. M., 30-04-90, P3; C31554, SHANNON NATIONAL PARK DOG POOL ON SHANNON RIVER, -34 7667°S 116.3667°E, WALDOCK, J. M. & SAMPEY, A., 09-06-93, C31555, CAREY BROOK AT VASSE HIGHWAY, -34 4161°S 115.8100°E, HARVEY, M. S., 18-08-97, B10.

Diagnosis: Habitus roller. Body convex with definite patterning and strong colouration. Pereonal epimeron 1 with ventral groove (sulcus marginali) narrowing anteriorly. Eye large and frontal ridge in a smooth and distinct arc but generally flat to dorsal surface of head. Pereonites smooth and pale cream with brown markings. Posterior margin of pereonal epimeron 1 produced backwards. Inner lobe of epimeron 1 smaller than posterior lateral epimeron border and not visible in lateral view. Posterior margin of pereonal epimeron 7 without posterior kink. Pereonal epimeron 2 rounded. Uropods broad and short. Telson barely wider at distal margin than narrowest point. Narrowest point approximately at midpoint.

Remarks: Spherillo species 3 is similar in colour and size and general morphology to both Cubaris species 3 and Buddelundia species 6. These three species can co-occur in the wetter parts of the karri forests in the far south of the region. Buddelundia species 6 is the most widely distributed, followed by Spherillo species 3 and then Cubaris species 3. Fortunately, the species can be separated easily by distinctive generic characters. Buddelundia by the nature of the pleopods, and Spherillo and Cubaris by the nature of the lobes of pereonal epimeron 1.

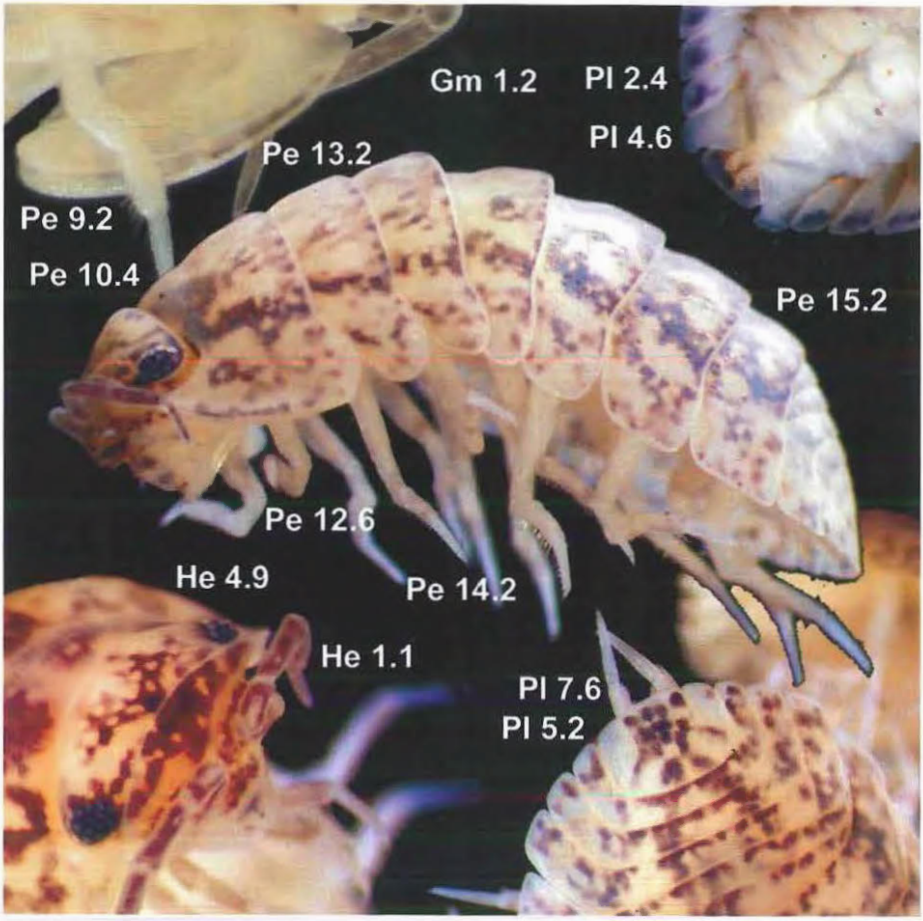


Plate 3.83. Spherillo species 3 from Shannon National Park (C30591) (length 6 mm).

3.17.3.5. Spherillo species 4

Plate 3.8, He 4.11; Plate 3.14, He 10.3, Plate 3.26, Pe 10.7; Plate 3.28, Pe 12.11; Plate 3.40, Pl 7.10; Plate 3.84.

Armadillidae sp. 7 Judd & Horwitz, 2003

MATERIAL EXAMINED: C21085, YORK, -31.8833°S 116.7667°E, BANNISTER, J., 16-11-91, L10; C21086, YORK, -31.8833°S 116.7667°E, BANNISTER, J., 02-11-91, L10; C21092, GIDGEGANNUP WATERFORD ROAD, -31.8500°S 116.1833°E, HARVEY, M S, 12-01-92, L10; C29714, YORK, -31.8833°S 116.7667°E, BANNISTER, J., 16-11-91, L10; C29715, MT COOKE, -32.4167°S 116 3000°E, WALDOCK, J M, 26-12-91, P3, C30626/7, OCCIDENTAL FOREST BLOCK DALE ROAD, -32.1050°S 116 2570°E, JUDD, S, 04-11-98, L10, C30669, ST. RONANS NATURE RESERVE, -31 8730°S 116 6400°E, JUDD, S, 21-10-98, G30, C30670, MONADNOCKS CONSERVATION PARK MARGINATA ROAD, -32.2420°S 116 2050°E, JUDD, S, 04-11-98, L10, C30671/2, MONADNOCKS CONSERVATION PARK MILLARS LOG ROAD, -32 3950°S 116 3350°E, JUDD, S., 05-11-98, L10; C30673, MOUNT DALE, -32.1259°S 116 2951°E, WATSON, A, 01-10-01, P3, C30674, MOUNT DALE, -32.1259°S 116.2951°E, JUDD, S. & WATSON, A, 26-06-01, G10, C30675/6, MOUNT DALE, -32.1137°S 116.2898°E, WATSON, A., 01-10-01, P3; C30677/9, MOUNT DALE, -32 1011°S 116.2875°E, WATSON, A, 01-10-01, P3; C30680/1, MOUNT DALE, -32 0899°S 116 2961°E, WATSON, A., 01-10-01, P3; C30682, MOUNT DALE, -32 1193°S 116 2912°E, WATSON, A., 01-10-01, P3; C30683/4, MOUNT DALE, -32.1220°S 116.2926°E, WATSON, A., 01-10-01, P3; C30685/7, MOUNT DALE, -32 1071°S 116.2848°E, WATSON, A., 01-10-01, P3, C30688/91, MOUNT DALE, -32.1237°S 116.2934°E, WATSON, A., 01-10-01, P3; C30692, MOUNT DALE, -32 1028°S 116.2861°E, WATSON, A., 01-10-01, P3; C30693/95, MOUNT DALE, -32.0918°S 116.2779°E, WATSON, A., 01-10-01, P3; C30696, MOUNT DALE, -32.0918°S 116.2779°E, JUDD, S. & WATSON, A., 26-06-01, G10; C30697, MOUNT DALE, -32.0878°S 116 2784°E, WATSON, A., 01-10-01, P3; C30698/700, MOUNT DALE, -32.0834°S 116.2831°E, WATSON, A., 01-10-01, P3; C30701, MOUNT DALE, -32.0834°S 116.2831°E, JUDD, S. & WATSON, A., 14-12-01, G10, C30702/4, MOUNT DALE, -32.0940°S 116.2804°E, WATSON, A., 01-10-01, P3, C30705/7, MOUNT DALE, -32.0885°S 116 2810°E, WATSON, A., 01-10-01, P3; C30708, MOUNT DALE, -32 0885°S 116.2810°E, JUDD, S. & WATSON, A., 21-06-01, G10; C30709, MOUNT DALE, -32 0885°S 116.2810°E, JUDD, S. & WATSON, A., 11-10-01, G10, C30710, MOUNT DALE, -32.0992°S 116 2851°E, WATSON, A., 01-10-01, P3; C30711/2, MOUNT DALE, -32.1062°S 116 2815°E, WATSON, A., 01-10-01, P3, C30713, MOUNT DALE, -32 1040°S 116 2766°E, WATSON, A., 01-10-01, P3; C30714/19, MOUNT DALE, -32 1120°S 116.2875°E, WATSON, A., 01-10-01, P3; C30720, MOUNT DALE, -32 1019°S 116 2716°E, WATSON, A., 01-10-01, P3; C31578, MT COOKE, BASE OF MOUNT COOKE, -32 4167°S 116 3000°E, HARVEY, M. S., WALDOCK, J. M. & PETERSON, M., 07-08-90; C31579, MT COOKE, -32 4167°S 116 3000°E, HARVEY, M. S. & WALDOCK, J. M, 27-04-92, C31580, YORK 10 KM SW, -31 9500°S 116 5167°E, BANNISTER, J., 15-08-93, L10; C31581, KARRAGULLEN, -32.1167°S 116.1500°E, GRAHAM, R, 23-10-99, B40; C31582, KARRAGULLEN, -32.1167°S 116 1500°E, GRAHAM, R., 26-06-99, B40; C31583, DRYANDRA WOODLANDS, -32.7333°S 116 9500°E, GRAHAM, R., 26-06-99, B40; C31584, ASHENDON ROAD OFF BROOKTON HIGHWAY, -32 4000°S 116.1833°E, GRAHAM, R, 23-10-99, B40, C31585, BERAKING POOL ROAD OFF BROOKTON HIGHWAY, -32.2167°S 118.3500°E, GRAHAM, R, 26-10-99, B40; C31586, BROOKTON NATURE RESERVE, -32.4000°S 116.7333°E, GRAHAM, R., 28-10-99, B40; C31587, MT DALE WITHIN 300M OF SUMMIT, -32.1333°S 116.3000°E, JUDD, S, 29-03-00, G30.

Diagnosis: Habitus roller. Highly convex. Eyes large and frontal ridge in smooth, flattened arc. Pereonal epimeron 1 without ventral groove (sulcus marginali). Posterior margin of pereonal epimeron 1 angled moderately backward. Inner lobe clearly visible beyond posterior lateral epimeron border in lateral view. Lobes sub equal in length but posterior lateral epimeron border appears truncate. Pereonal epimeron 2 slightly rounded. Pereonites smooth. Pereonal epimeron 7 with slight kink in posterior margin. Pereonal epimeron 6 with posterior margin curved and angled backward giving it a characteristic rounded shape. Uropod protopodites short and not tapering distally. Telson short with distal border not much wider than midpoint and with angular appearance.

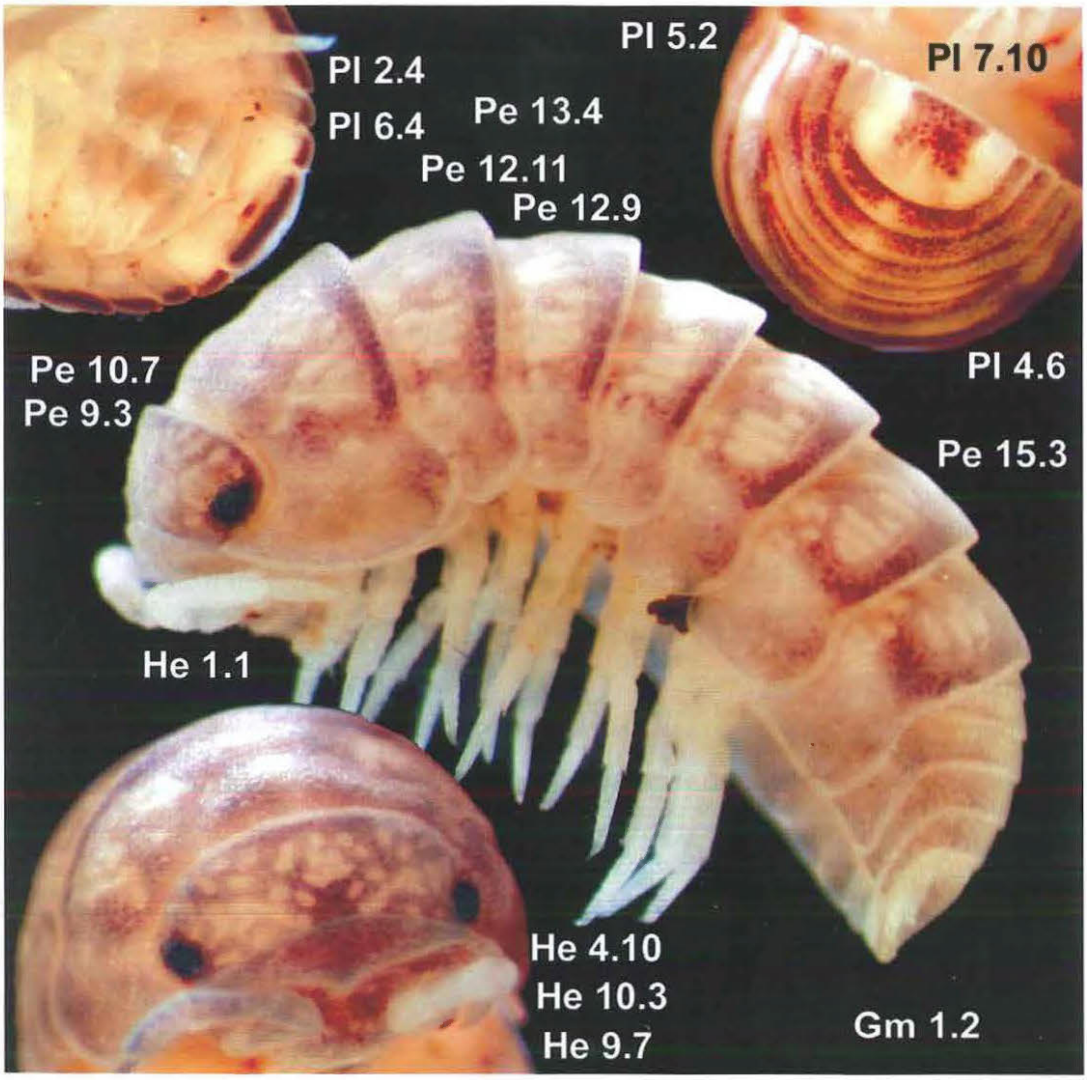


Plate 3.84. Spherillo **species 4 from York (C21085) (length 4.5 mm).**

3.17.3.6. Spherillo species 5

Plate 3.8, He 4.10; Plate 3.13, He 9.7; Plate 3.14, Pe 10.4; Plate 3.20, Pe 4.3; Plate 3.26, Pe 10.4; Plate 3.26, Pe 10.8; Plate 3.28, Pe 2.9; Plate 3.28, Pe 12.12; Plate 3.30, Pe 14.2; Plate 3.31, Pe 15.3; Plate 3.39, Pl 6.4; Plate 3.40, Pl 7.11; Plate 3.85.

Armadillidae sp. 1 Judd & Horwitz, 2003

MATERIAL EXAMINED: C16942, DWELLINGUP LANE POOLE RESERVE, -32.8167°S 116.0833°E, MUELLER, O., 26-07-86, C20210, WILSON INLET, -34 9833°S 117 3500°E, HARVEY, M. S & BLOSFELDS, M E., 21-02-90; C30617, JOHN FOREST NATIONAL PARK (SCARP), -31.8900°S 116 0870°E, JUDD, S , 11-08-98, B40; C30618, CLEAVE ROAD OFF SCOTT RD, -34.4180°S 115.7930°E, JUDD, S., 14-08-98, B40; C30619, CANNING RIVER (BELOW CANNING DAM), -32 1430°S 116.1100°E, JUDD, S , 25-08-98, G40; C30620, ST. RONANS NATURE RESERVE, -31 8730°S 116 6400°E, JUDD, S., 21-10-98, L20; C30621, STRANGE ROAD NATURE RESERVE, -32 4030°S 116 6150°E, JUDD, S., 26-10-98, G40; C30622, JINGALUP NATURE RESERVE, -34.0130°S 117 0130°E, JUDD, S., 29-10-98, L10; C30623/4, JINGALUP NATURE RESERVE, -34.0130°S 117 0130°E, JUDD, S., 29-10-98, L42; C30625, JINGALUP NATURE RESERVE, -34 0130°S 117 0130°E, JUDD, S., 29-10-98, R1; C30628, AMPHION FOREST BLOCK, -32.7920°S 116.1870°E, JUDD, S , 10-11-98, L10; C30629, NOGGERUP CONSERVATION PARK, -33 6220°S 116.1230°E, JUDD, S., 24-11-98, G30; C30630/1, BRIDGETOWN WEST NATURE RESERVE, -33 9520°S 116.0780°E, JUDD, S , 01-12-98, G40; C30632, BRIDGETOWN WEST NATURE RESERVE, -33 9520°S 116.0780°E, JUDD, S., 01-12-98, G30; C30633, BRIDGETOWN JARRAH PARK, -34 0300°S 115.9830°E, JUDD, S., 01-12-98, L40, C30634, BRIDGETOWN JARRAH PARK, -34 0300°S 115.9830°E, JUDD, S., 01-12-98, L10; C30635/6, MILYEANNUP CONSERVATION PARK?, -34.0900°S 115.5670°E, JUDD, S , 02-12-98, L10, C30637, MILYEANNUP CONSERVATION PARK?, -34.0900°S 115.5670°E, JUDD, S., 02-12-98, G40; C30638, ST JOHNS CONSERVATION PARK, -33.9450°S 115 6900°E, JUDD, S., 02-12-98, G40, C30639, ELLIS CREEK ROAD, -33.9350°S 115 8820°E, JUDD, S , 03-12-98, G20; C30640, MULLALYUP CONSERVATION PARK, -33.7150°S 115 8680°E, JUDD, S , 03-12-98, G40; C30641, LEEUWIN NATURALISTE NATIONAL PARK (QUININUP KARRI), -33.7350°S 115.0070°E, JUDD, S., 07-12-98, B10, C30642/3, SCOTT RIVER NATIONAL PARK, -34.3030°S 115.1730°E, JUDD, S , 09-12-98, L10; C30644, SCOTT RIVER NATIONAL PARK, -34.3030°S 115.1730°E, JUDD, S., 09-12-98, G40, C30645/6, GINGILUP SWAMPS NATURE RESERVE, -34 3320°S 115.4400°E, JUDD, S , 09-12-98, G40; C30647/8, LEEUWIN NATURALISTE NATIONAL PARK KARRI NEAR HAMELIN BAY, -34 2000°S 115.0720°E, JUDD, S., 10-12-98, B10; C30649, LEEUWIN NATURALISTE NATIONAL PARK KARRI NEAR HAMELIN BAY, -34.2000°S 115.0720°E, JUDD, S., 10-12-98, L10; C30650, MARGARET RIVER CREEK, -33 9350°S 115.0650°E, JUDD, S., 10-12-98, B10, C30651, MARGARET RIVER CREEK, -33 9350°S 115.0650°E, JUDD, S., 10-12-98, B40; C30652, MARBELUP NATURE RESERVE, -34 9920°S 117.7220°E, JUDD, S , 17-12-98, B40; C30653, WEST CAPE HOWE NATIONAL PARK, -35.0820°S 117 6430°E, JUDD, S , 17-12-98, B10; C30654, DOWN ROAD NATURE RESERVE, -34 9550°S 117 7580°E, JUDD, S., 20-12-98, B40, C30655, PARDELUP NATURE RESERVE, -34 6720°S 117.4150°E, JUDD, S., 20-12-98, L10; C30656, WALPOLE NORNALUP NATIONAL PARK TINGLEWOOD, -35.0030°S 116.6380°E, JUDD, S , 07-01-99, B40; C30657, RATE BLOCK, -34 8350°S 117.0070°E, JUDD, S., 01-09-99, B10, C30658, RATE BLOCK, -34.8350°S 117 0070°E, JUDD, S , 01-09-99, L41; C30659, CLEAR HILLS/WATERSHED ROAD, -34.6980°S 117 1820°E, JUDD, S., 01-09-99, R3; C30660, ORDNANCE STATE FOREST, -34 6680°S 116 6650°E, JUDD, S , 10-01-99, G20; C30661, ORDNANCE STATE FOREST, -34 6680°S 116 6650°E, JUDD, S., 10-01-99, B10; C30662, WALPOLE NORNALUP NATIONAL PARK SAPPER'S BRIDGE, -34 9600°S 116 8220°E, JUDD, S., 10-01-99, E1, C30663, KINGSTON ROAD, -34.0850°S 116 3500°E, JUDD, S , 24-01-99, G30; C30664, WARREN RIVER/DEESIDE COAST RD., -34 3920°S 116.4030°E, JUDD, S., 24-01-99, L10, C30665/6, LAKE UNICUP NATURE RESERVE, -34 3680°S 116.7000°E, JUDD, S., 26-01-99, L10, C30667, SHANNON RIVER/CHESAPEAKE RD , -34.8420°S 116 3700°E, JUDD, S., 27-01-99, B10, C30668, BOMBAKUP STATE FOREST, -34 6080°S 116.0320°E, JUDD, S , 28-01-99, B10; C31561, ARMADALE, -32.1500°S 116 0000°E, COLLECTOR UNKNOWN, 14-05-39, C31562, PEMBERTON, -34.4500°S 116.0333°E, NICHOLLS COLLECTION, 20-01-43, B10, C31583, ARMADALE, -32.1500°S 116 0000°E, NORRIS, K. R., 12-05-34, C31564, PEMBERTON HL61 BIG BROOK, -34.2667°S 115 9333°E, SPRINGETT, J. A., ??-??-72; C31565, SHANNON RIVER DOG POOL, -34.7667°S 116 3667°E, HARVEY, M. S. & BLOSFELDS, M E , 02-03-89, B10; C31566, DALGARUP NATURE RESERVE, -34 0167°S 115 9333°E, HARVEY, M S & BLOSFELDS, M. E., 17-04-95, B10, C31567, MUNDARING WEIR, -31.9667°S 116 1667°E, WALDOCK, J M., 06-11-88, L10; C31568, MARGARET RIVER BORANUP ROAD 20 KM SOUTH, -33.9667°S 115 0667°E, HARVEY, M. S & BLOSFELDS, M. E., 15-02-90, B10, C31569, MARGARET RIVER BORANUP ROAD 19 KM SOUTH, -33 9500°S 115.0500°E, HARVEY, M. S & BLOSFELDS, M E , 15-02-90, B10, C31570, SHANNON RIVER NELSON, -34 7167°S 116 3500°E, HARVEY, M S. & BLOSFELDS, M E., 18-02-90, B10; C31571, STIRLING RANGE NATIONAL PARK MOINGUP SPRING, -34 4000°S 118 1000°E, WALDOCK, J M & SAMPEY, A., 10-06-93; C31572, KARRAGULLEN, -32.1167°S 116 1500°E, GRAHAM, R , 26-06-99, B40, C31573, KARRAGULLEN, -32 1167°S 116.1500°E, GRAHAM, R., 23-10-99, B40; C31574, DRYANDRA WOODLANDS, -32 7333°S 116 9500°E, GRAHAM, R., 26-08-99, B20; C31575, DRYANDRA WOODLANDS, -32 7333°S 116 9500°E, GRAHAM, R , 26-06-99, B40; C31576, LESLEY FOREST RESERVE BROOKTON HIGHWAY, -32.2000°S 116 2667°E, GRAHAM, R., 26-06-99, B40, C31577, WALPOLE NORNALUP NATIONAL PARK TINGLE CREEK FOREST, -34 9750°S 116.7833°E, VAN HEURCK, P ET AL., 16-05-97, B40.

Diagnosis: Habitus roller. Highly convex. Eyes large and frontal ridge in smooth, arc raised slightly from dorsal surface. Pereonal epimeron 1 without ventral groove (sulcus

marginali). Pereonal epimeron 1 angled strongly backward with posterior lateral epimeron border slightly longer than inner lobe but inner lobe just visible beyond posterior lateral epimeron border in lateral view. Pereonal epimeron 2 slightly rounded. Pereonite 1 usually with distinct bumps and depressions on dorsal surface. Otherwise, pereonites smooth. Pereonal epimeron 7 with slight kink in posterior margin. Pereonal epimeron 6 with posterior margin curved and angled backward giving it characteristic shape. Uropod protopodites short and not tapering distally. Telson short with distal border not much wider than midpoint and with angular appearance.

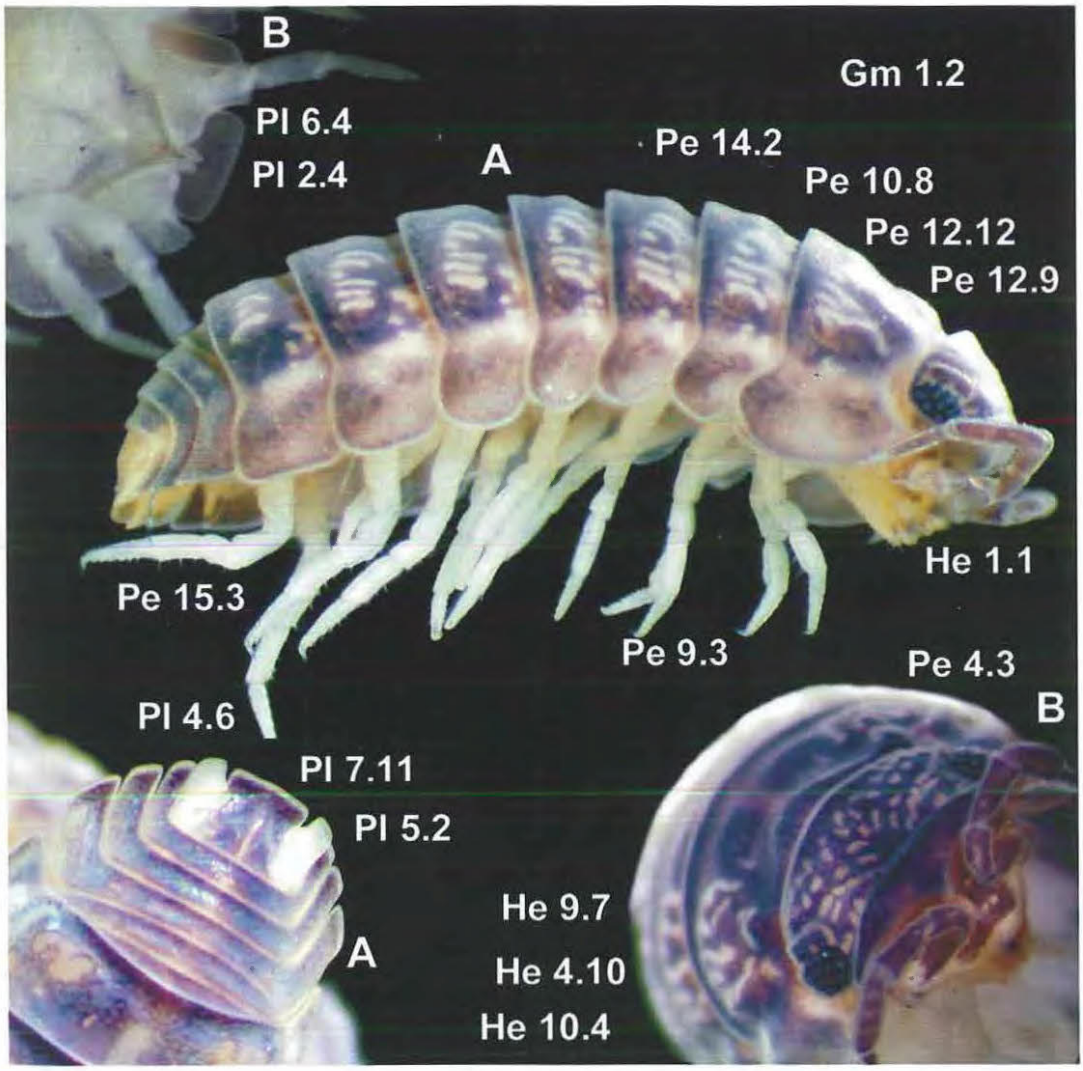


Plate 3.85. Spherillo species 5 from (A) Milyeannup Conservation Park (C30637) (length 5 mm) and (B) St. John's Conservation Park (C30638) (length 5 mm).

3.17.4. GENUS ACANTHODILLO VERHOEFF

Diagnosis: This diagnosis is from Lewis (1998b, p. 714). "Short thickset antenna with eccentrically inserted flagellum; dorsal surface usually with prominent ornamentation of tubercles, spines, crests and scales; ventral lobes on epimera 1-2 or 1-3; eye often small of 2-3 ommatidia, but may have up to 20 ommatidia; epimera 1 may be split posteriorly; posterior angle between epimera and tergites often acute, sides of telson may be parallel or with central constriction; pleopodal lungs present in pleopods 1-5". Plate 3.86 illustrates some of these characters.

Remarks: The exopodites of pleopod 5 are very small in the five species of Acanthodillo described here. They are sometimes partially obscured by the exopods of pleopods 4. However, the pleopod exopodites are not interlocking as in Buddelundia (Subsection 3.17.6). Examination of live specimens appeared to show pleopodal lungs present in only the first four pairs of pleopod exopodites. However, this needs to be confirmed by dissection and mounting of pleopods. If this diagnoses proves correct, a new genus would be necessary to accommodate the following five taxa.

Plate 3.86. Typical features of the genus Acanthodillo. Relatively short and thickset antenna, small eye (~5 ommatidia) and a dorsal surface both tuberculate and with conspicuous scales. Ventral lobes just visible on epimera 1 and 2. Specimen is Acanthodillo species 4 (C31608).

3.17.4.1. Acanthodillo flavus (Budde-Lund, 1912)

Plate 3.20, Pe 4.1; Plate 3.22, Pe 6.1; Plate 3.87.

Armadillo flavus Budde-Lund, 1912

Armadillo flavus Vandel, 1973

Buddelundia flava Vandel, 1973

TYPE MATERIAL EXAMINED: C374, ARMADILLO FLAVUS, SYNTYPE, MUNDARING WEIR, HAMBURG EXPEDITION STN 101, WA, 09-08-05.

MATERIAL EXAMINED: C29702, MUNDARING, -31.9000°S 116.1667°E, CLARKE, J., ??-??-??; C31611, LUDLOW, -33.6167°S 115.4833°E, NICHOLLS COLLECTION, ??-??-??, G30; C31612, MT COOKE, -32.4167°S 116.3000°E, HARVEY, M. S., WALDOCK, J. M. & MAIN, B. Y., 19-09-91, R1; C31613, MT COOKE, -32.4167°S 116.3000°E, HARVEY, M. S. & WALDOCK, J. M., 16-06-91, P3; C31615, STIRLING RANGE NP 6 M DOWN STIRLING RANGE DRIVE, -34.4000°S 117.9833°E, HARVEY, M. S. & WALDOCK, J. M., 01-04-93; C32075, CARDUP RESERVE, -32.2431°S 115.9856°E, WALDOCK, J. M., WEST, P. L. & LONGBOTTOM, A., 17-06-96, P3; C32076, CARDUP RESERVE, -32.2444°S 115.9875°E, WALDOCK, J. M., WEST, P. L. & LONGBOTTOM, A., 17-06-96, P3; C32077, CARDUP RESERVE, -32.2481°S 115.9856°E, WALDOCK, J. M., WEST, P. L. & LONGBOTTOM, A., 17-06-96, P3; C32078, TALBOT ROAD RESERVE, -31.8733°S 116.0478°E, WALDOCK, J. M. ET AL., 18-11-93, P3.

Diagnosis: Habitus roller/clinger. Slightly concave in appearance. Pereonal epimeron 1 without ventral groove (sulcus marginali). Eye small to moderate size and frontal ridge raised from dorsal surface of head. All pereonal epimera strongly curved and rounded backwards, most evident in pereonal epimera 1-5. Creamy white colour with very distinctive sculptured pattern on dorsal surface of pereonite 1 (more pronounced in juveniles). Inner lobe of pereonal epimera 1 very small but visible in lateral view due to the truncate nature of posterior lateral epimeron border. Telson distinctly hourglass shaped sometimes with longitudinal anterior furrow. Lateral margins of telson curved.

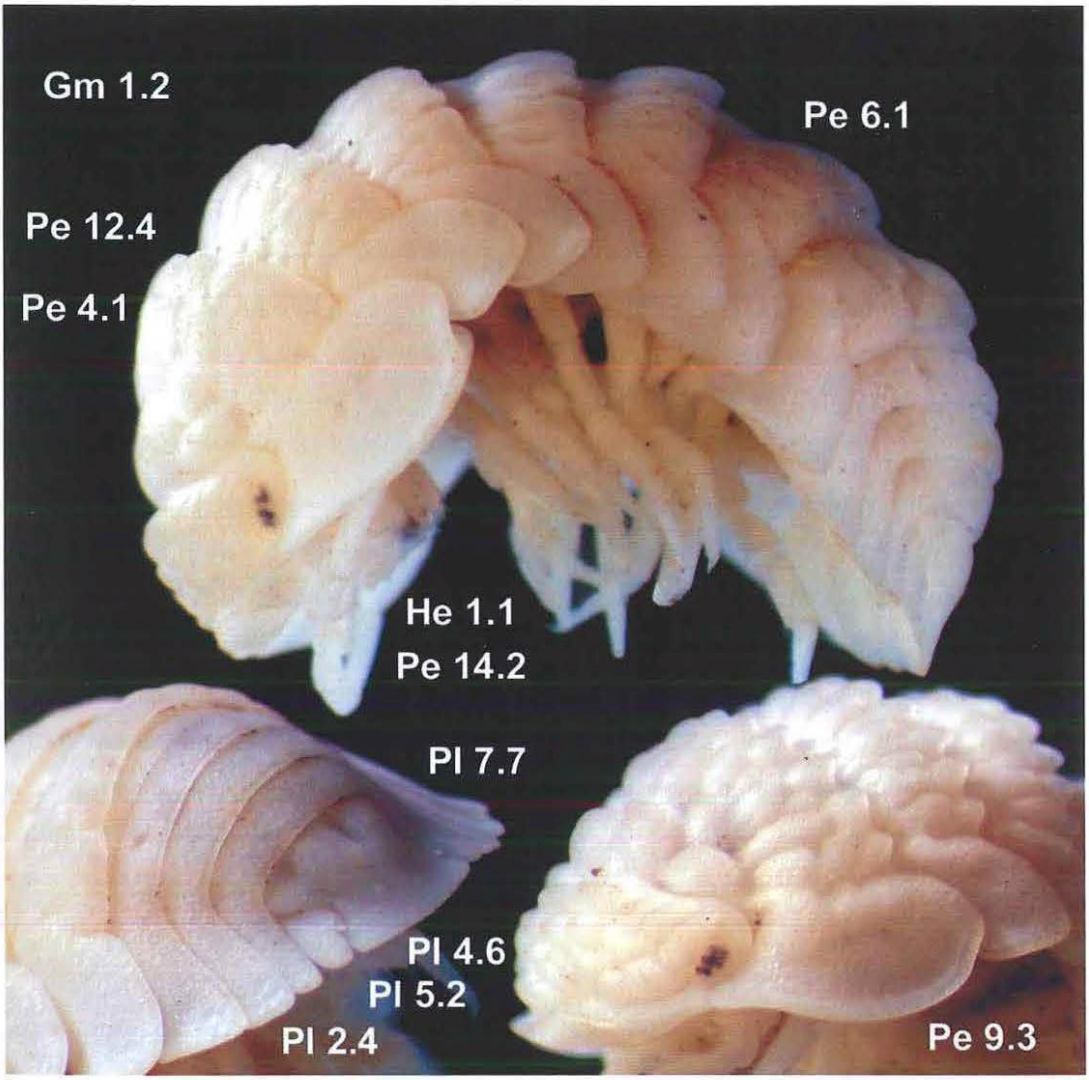


Plate 3.87. Acanthodillo flavus **from Mount Cooke (C31612) (length 6 mm).**

3.17.4.2. Acanthodillo species 1

Plate 3.20, Pe 4.2; Plate 3.22, Pe 6.2; Plate 3.88

MATERIAL EXAMINED: C30747, BOOLADING NATURE RESERVE, -33 3500°S 116.6270°E, JUDD, S , 30-10-98, G30, C31614, MT OBSERVATION, -31.9000°S 116 5500°E, HARVEY, M S. & BLOSFELDS, M. E , 13-08-94, R1.

Diagnosis: Habitus roller. Slightly concave in appearance. Eye of moderate size and frontal ridge raised slightly from dorsal surface of head. Pereonal epimeron 1 without a ventral groove (sulcus marginali). All pereonal epimera moderately curved and angled backwards. Inner lobe of pereonal epimeron 1 slightly longer than epimeron border and is visible in lateral view. Brownish colouring with irregular bumps on all pereonites. Uropods long and tapering and telson hourglass shaped with narrowest point slightly posterior of the mid point. Lateral margins of telson curved.

Remarks: This species is similar is its overall general morphology to Acanthodillo commensalis (Baker 1913) particularly in the shape of the epimera and the arrangement and shape of the tubercles. Although Baker's figures were very small and hard to interpret, this species appears to differ principally from A. commensalis in the form of the inner lobe of the first pereonal epimeron. In A. commensalis it is distinctly shorter than the posterior lateral epimeron border while in this species it is longer. The telson of A. commensalis also has two anterior bumps either side of the longitudinal midline a character shared by Acanthodillo species 4.

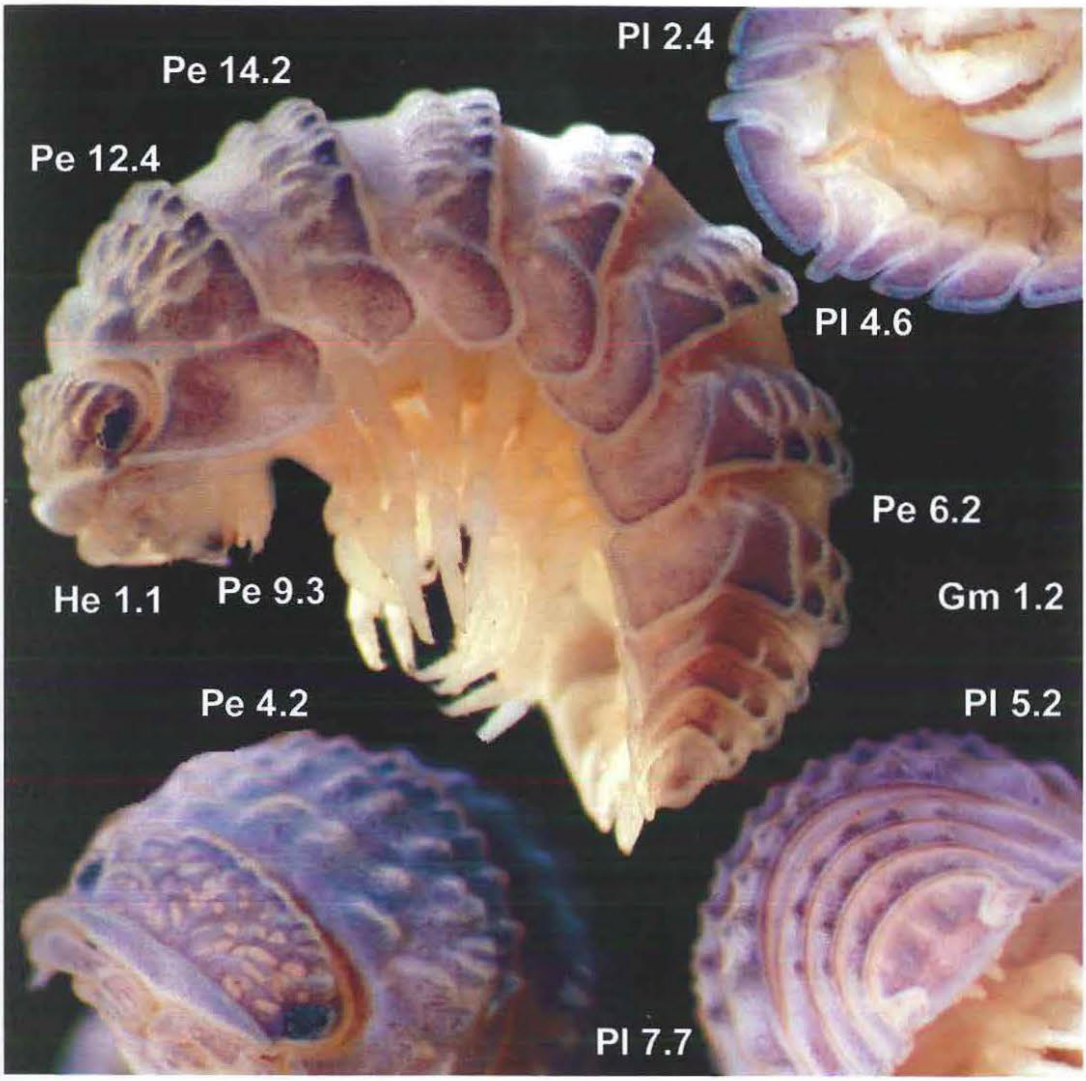


Plate 3.88. Acanthodillo **species 1. from Boolading Nature Reserve (C30747) (length 6 mm).**

3.17.4.3. Acanthodillo species 2

Plate 3.29, Pe 13.3; Plates 3.89a, 3.89b.

Armadillidae sp. 3 Judd & Horwitz, 2003

MATERIAL EXAMINED C18408, WOOROLOO NEAR HOUSE CREEK, -31 8000°S 116 3167°E, BOWLEY, E A., 17-08-32; C30737, MOKINE NATURE RESERVE, -31 7970°S 116 5930°E, JUDD, S., 21-10-98, S1, C30738, MOKINE NATURE RESERVE, -31.7970°S 116 5930°E, JUDD, S., 21-10-98, R2; C30739, MOKINE NATURE RESERVE, -31 7970°S 116.5930°E, JUDD, S., 21-10-98, G30; C30740, BOOLADING NATURE RESERVE, -33 3500°S 116 6270°E, JUDD, S., 30-10-98, G30; C30741, SEVEN MILE WELL NATURE RESERVE, -31 0650°S 116 2020°E, JUDD, S., 11-10-98, L41; C30742, SEVEN MILE WELL NATURE RESERVE, -31 0650°S 116 2020°E, JUDD, S., 11-10-98, R1; C31602, MUNDARING BB87 HAVEL'S PLOT 3, -31 9000°S 116 1667°E, SPRINGETT, J A., 05-11-71; C31603, BULLSBROOK LAKE HOSKING, -31.6667°S 115 9833°E, ??-??-??, C31604, GOOSEBERRY HILL, -31 9500°S 116 0500°E, NICHOLLS COLLECTION, ??-06-32

Diagnosis: Habitus roller/clinger. Moderately convex. Eyes moderately developed for genus. Frontal ridge in smooth arc but not significantly raised from dorsal surface of head. Pereonal epimeron 1 almost straight with both inner and posterior lateral epimeron border small and sub-equal in length. Pereonal epimeron 1 without ventral groove (sulcus marginali). Pereonal epimeron 2 terminating in point. Pereonites generally smooth or very slightly bumpy (possibly more bumpy in juveniles). Pereonal epimeron 7 with very slight posterior kink. Uropods short and broad and telson broad and relatively long. Telson hourglass shaped with narrowest point close to midpoint and distal margin wider than the midpoint.

Remarks: The two plates probably represent separate species. They are grouped based on the character of the shape of the pereonal epimeron 2. There were only two specimens collected from Seven Mile Well (Plate 3.89b), they are small and may be juveniles. Since the character of tuberculation has been observed to vary between adult and younger forms less emphasis is placed on this character here. More material of the latter, and a closer examination of both forms, is required to establish this beyond doubt. The species is not a typical acanthodillid in terms of the shape of the pereonal epimera of the presence of large surface scales. A new genus is probably needed to accommodate this taxon. However, due to the nature of the first two epimeral lobes and the size of the antenna, illustrated in Plate 3.88a it is placed here in the interim.

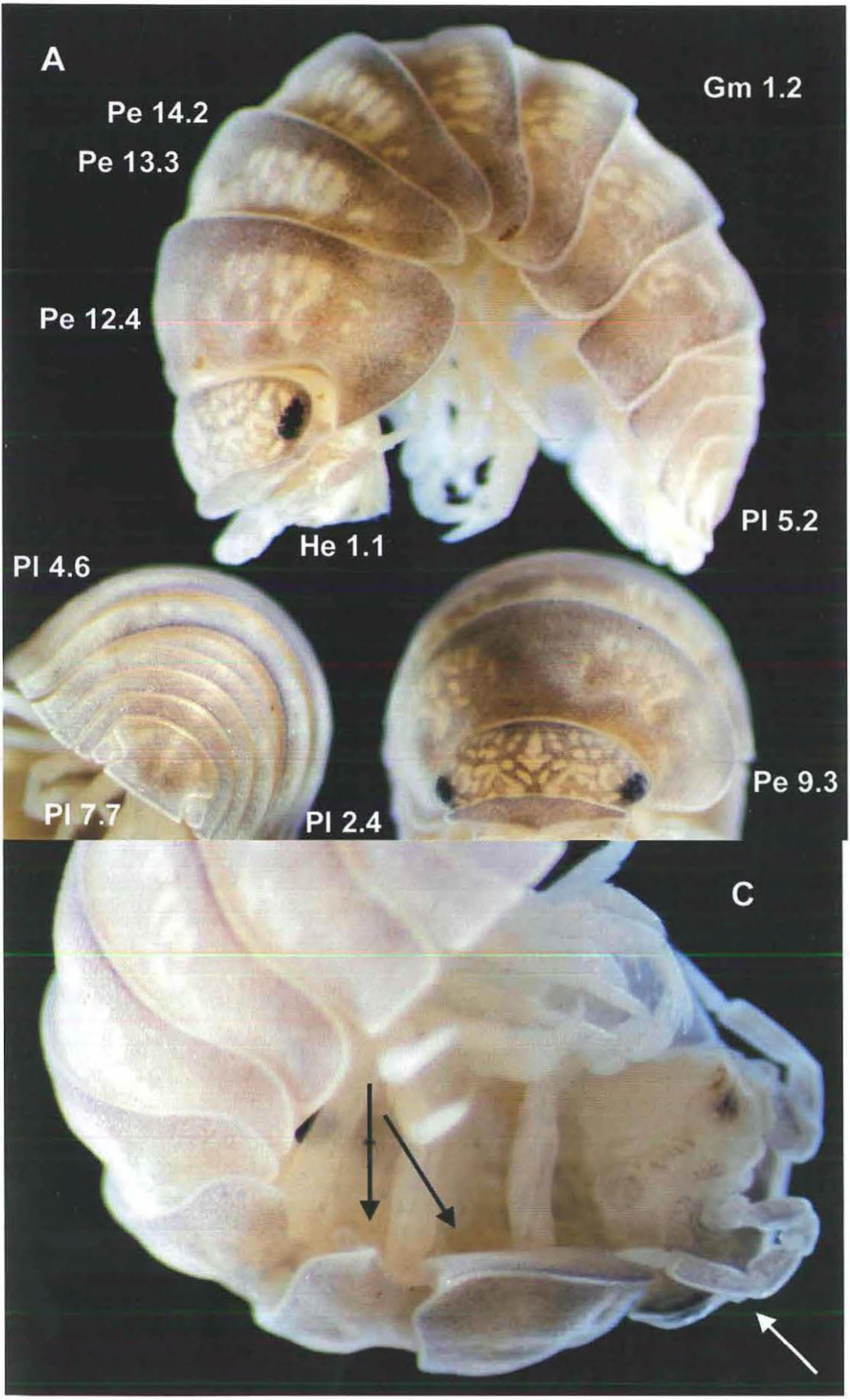


Plate 3.89a. Acanthodillo species 2 from Mokine Nature Reserve (C30737) (length 5 mm). Typical Acanthodillo antenna and epimeral lobes are illustrated in C.

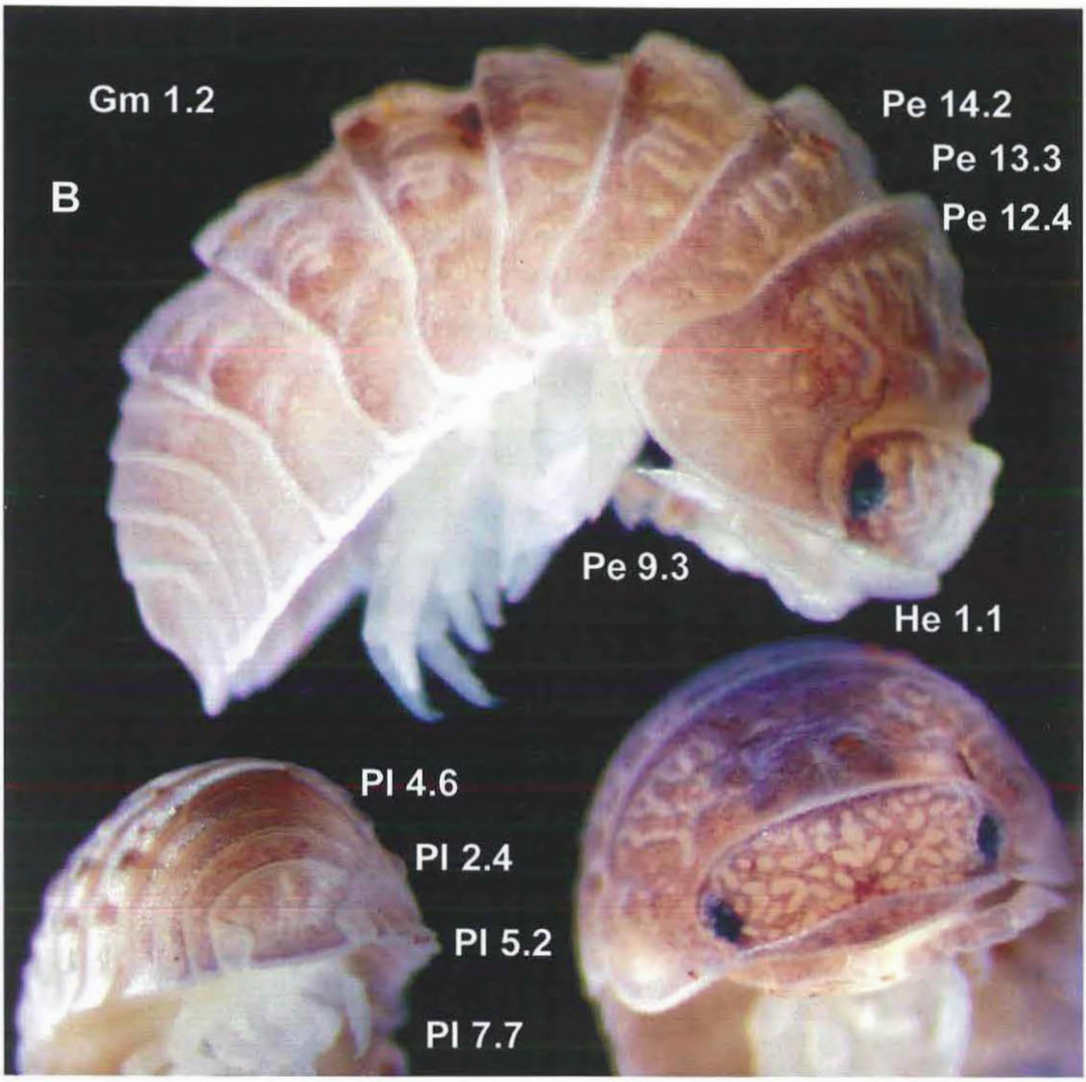


Plate 3.89b. Acanthodillo species 2 from Seven Mile Well Nature Reserve (C30741) (length 2.5 mm).

3.17.4.4. Acanthodillo species 3

Plate 3.17, Pe 1.23; Plate 3.28, Pe 12.7; Plate 3.90.

MATERIAL EXAMINED: C29709, DWELLINGUP LANE POOLE RESERVE, -32.8167°S 116.0833°E, MUELLER, O., 26-07-86.

Diagnosis: Habitus roller/clinger. Moderately concave. Pereonal epimeron 1 without ventral groove (sulcus marginali). Inner lobe of pereonal epimeron 1 of moderate size but visible in lateral view because posterior lateral epimeron border has rounded incision. Epimeron itself angled slightly backward. Pereonites with longitudinal rows of bumps and covered in fine setae. Uropods long and tapering. Telson hourglass shaped.

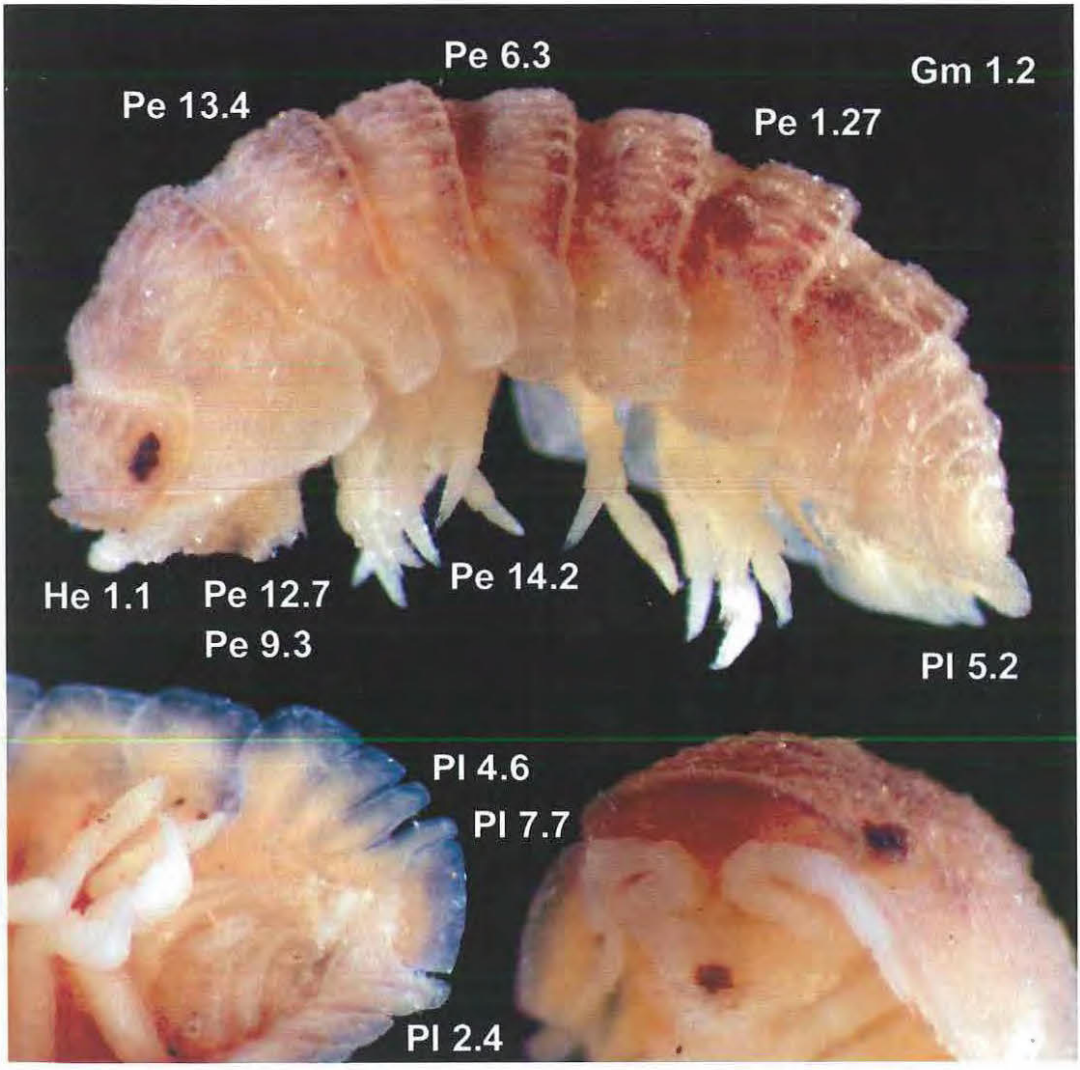


Plate 3.90. Acanthodillo species 3 from Lane Poole Reserve (C29709) (length 4 mm).

3.17.4.5. Acanthodillo species 4

Plate 3.9, He 5.5; Plate 3.13, He 9.5; Plate 3.14, He 10.1, Plate 3.17, Pe 1.24; Plate 3.25, Pe 9.3; Plate 3.26, Pe 10.5; Plate 3.28, Pe 12.8; Plate 3.38, Pl 5.2a; Plate 3.86; Plate 3.91.

?Armadillo bituberculatus sp. 3 Budde-Lund, 1912.

MATERIAL EXAMINED C30746, WEST CAPE HOWE NATIONAL PARK, -35.0820°S 117 6430°E, JUDD, S , 17-12-98, L10. C31607, TORNDIRRUP NATIONAL PARK 9 KM S OF ALBANY, -35 0900°S 117.8333°E, DYER, P H. & LYON, J L , 09-11-83, P1; C31608, TORBAY HEAD BECK'S PLACE COTTAGE SITE, -35 1333°S 117 6350°E, MAIN, B. Y., 19-02-83, P1.

Diagnosis: Habitus roller/creeper. Moderately concave. Eye small and frontal ridge projecting well above dorsal surface of head and of rounded sub triangular shape. Head with two well-defined bumps on dorsal surface, one behind each eye. Pereonal epimeron 1 without a ventral groove (sulcus marginali). Posterior lateral epimeron border of pereonal epimeron 1 truncate therefore, although Inner lobe is relatively small, it is visible in lateral view. Posterior margin of pereonal epimeron 1 almost straight. Pereonites with scaly appearance and well defined bumps arranged in longitudinal rows. Uropods long and tapering. Telson hourglass shaped, broad and wide with two bumps near anterior edge.

Remarks: This species is typical of the Australian Acanthodillo in that it agrees with Lewis' observations of ridges on the epimera tergite junction and large scales. The species described by Budde-Lund (1912) as Armadillo bituberculatus was collected from Torbay, which very close to the localities of the material examined here. Although there was no type material available to examine and the description given was incomplete, the partial description and the two distinct bumps behind the eyes suggest that this may be that species. The etymology of the name may have reflected the two bumps on the head.

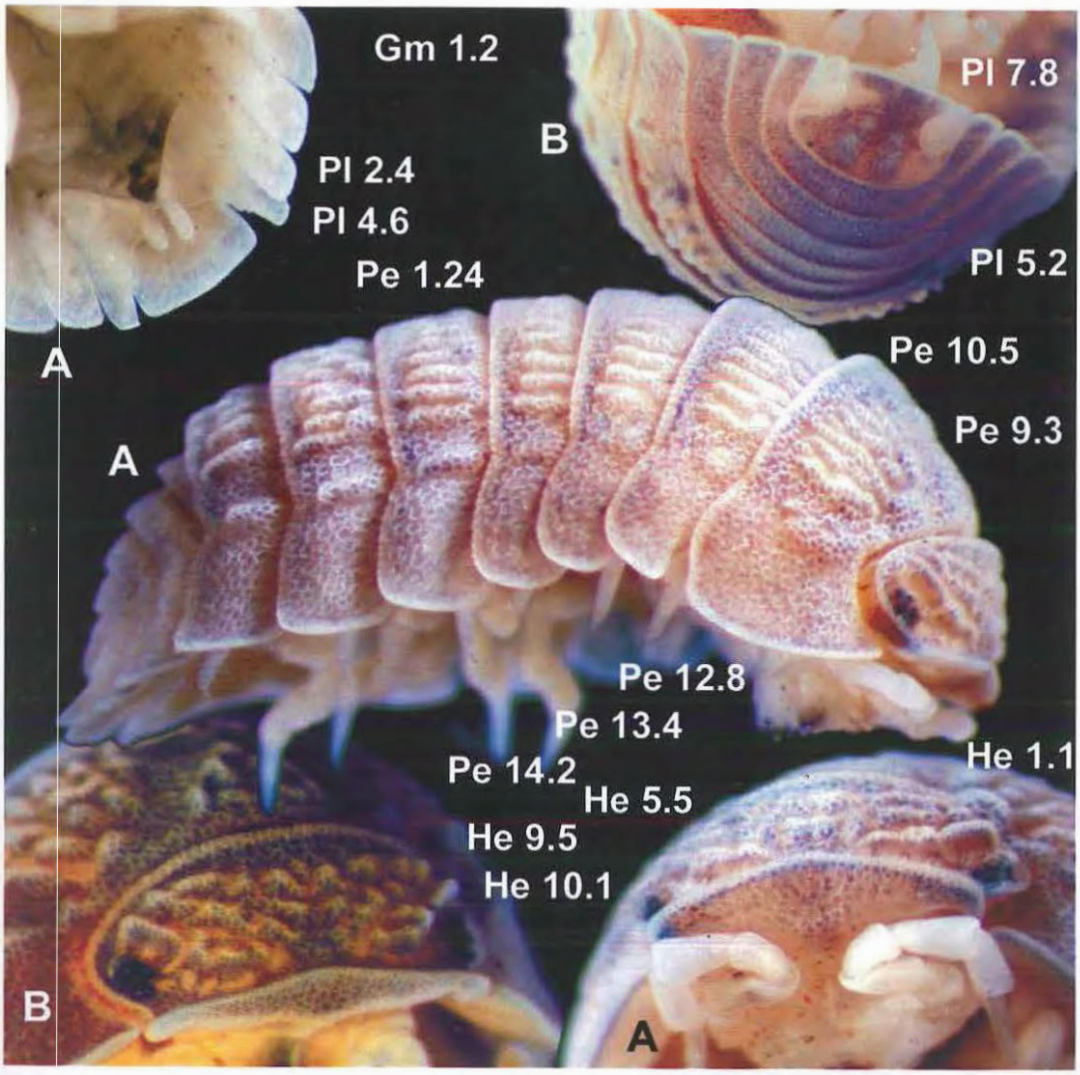


Plate 3.91. Acanthodillo species 4 from (A) Torbay Head (C31608) (length 6 mm) and (B) West Cape Howe National Park (C30746) (length 6 mm).

3.17.4.6. Acanthodillo species 5

Plate 3.22, Pe 6.3; Plate 3.26, Pe 10.6; Plate 3.28, Pe 12.4; Plate 3.28, Pe 12.10; Plate 3.31, Pe 15.4; Plate 3.39, Pl 6.5; Plate 3.40, Pl 7.9; Plate 3.92.

Armadillidae sp. 2 Judd & Horwitz, 2003

MATERIAL EXAMINED C5193, MANJIMUP, PERUP?, -34 3333°S 116 4500°E, GLAUERT, L., ??-03-36, G30, C30727, NARLINGUP NATURE RESERVE, -33 8630°S 116 8900°E, JUDD, S., 29-10-98, S1, C30728, NARLINGUP NATURE RESERVE, -33 8630°S 116 8900°E, JUDD, S., 29-10-98, G30; C30729/30, HADDLETON NATURE RESERVE, -33 6330°S 116 5980°E, JUDD, S., 29-10-98, G30; C30731/3, BOOLADING NATURE RESERVE, -33 3500°S 116 5270°E, JUDD, S., 30-10-98, G30; C30734, HARRIS DAM, -33 2550°S 116 1150°E, JUDD, S., 30-10-98, L20, C30735, PRESTON CONSERVATION PARK, -33 6030°S 116 0630°E, JUDD, S., 24-11-98, G30, C30736, BRIDGETOWN WEST NATURE RESERVE, -33 9520°S 116 0780°E, JUDD, S., 01-12-98, G30; C30748, DUNSBOROUGH CNR COMMONAGE/WILDWOOD RDS, -33 6920°S 115 0670°E, JUDD, S., 15-07-98, L10, C30749, MOUNT DALE, -32 1011°S 116 2875°E, WATSON, A., 01-10-01, P3; C30750/1, MOUNT DALE, -32 1028°S 116 2861°E, JUDD, S & WATSON, A., 26-06-01, G10, C30752, MOUNT DALE, -32 0885°S 116 2810°E, JUDD, S & WATSON, A., 21-06-01, G10; C30753, MOUNT DALE, -32 0869°S 116 2928°E, JUDD, S & WATSON, A., ??-06-01, G10, C30754, MOUNT DALE, -32 1062°S 116 2815°E, WATSON, A., 01-10-01, P3.

Diagnosis: Habitus roller. Slightly convex. Eyes small, frontal ridge a smooth flat arc not raised from the dorsal surface of the head. Pereonal epimeron 1 without a ventral groove (sulcus marginali). Pereonal epimeron 1 angled only slightly backward with inner lobe and posterior lateral epimeron border sub-equal in length. Inner lobe just visible in lateral view. Pereonal epimeron 2 square and truncate and angled only slightly backward. Pereonites with shallow bumps sometimes visible in longitudinal rows. Pereonal epimeron 7 without kink in posterior margin. Uropod protopodites moderately long and tapering slightly distally. Telson with distal border not much wider than midpoint with an angular medial constriction.

Remarks: The remarks made about Acanthodillo species 3 regarding the shape of the pereonal epimera of the presence of large surface scales apply also to this species. It is most similar to Acanthodillo species 3 and differs mainly in the shape of pereonal epimeron 2. A new genus implied for Acanthodillo species 3 would also accommodate this species. There is a superficial similarity between this species and Spherillo species 5. The following outlines the main distinguishing characteristics.

Table 3.3.
The principle distinguishing characteristics between Spherillo species 5 and Acanthodillo species 5.

Spherillo species 5	Acanthodillo species 5
Antenna of moderate length	Antenna relatively short
Pereonal epimeron 1 angled sharply backwards	Pereonal epimeron 1 angled slightly backwards
Schisma of pereonal epimeron 1 narrow	Schisma of pereonal epimeron 1 wide
Posterior kink in pereonal epimeron 7	Without Posterior kink in pereonal epimeron 7
Uropod protopodite short and broad	Uropod protopodite long and thin

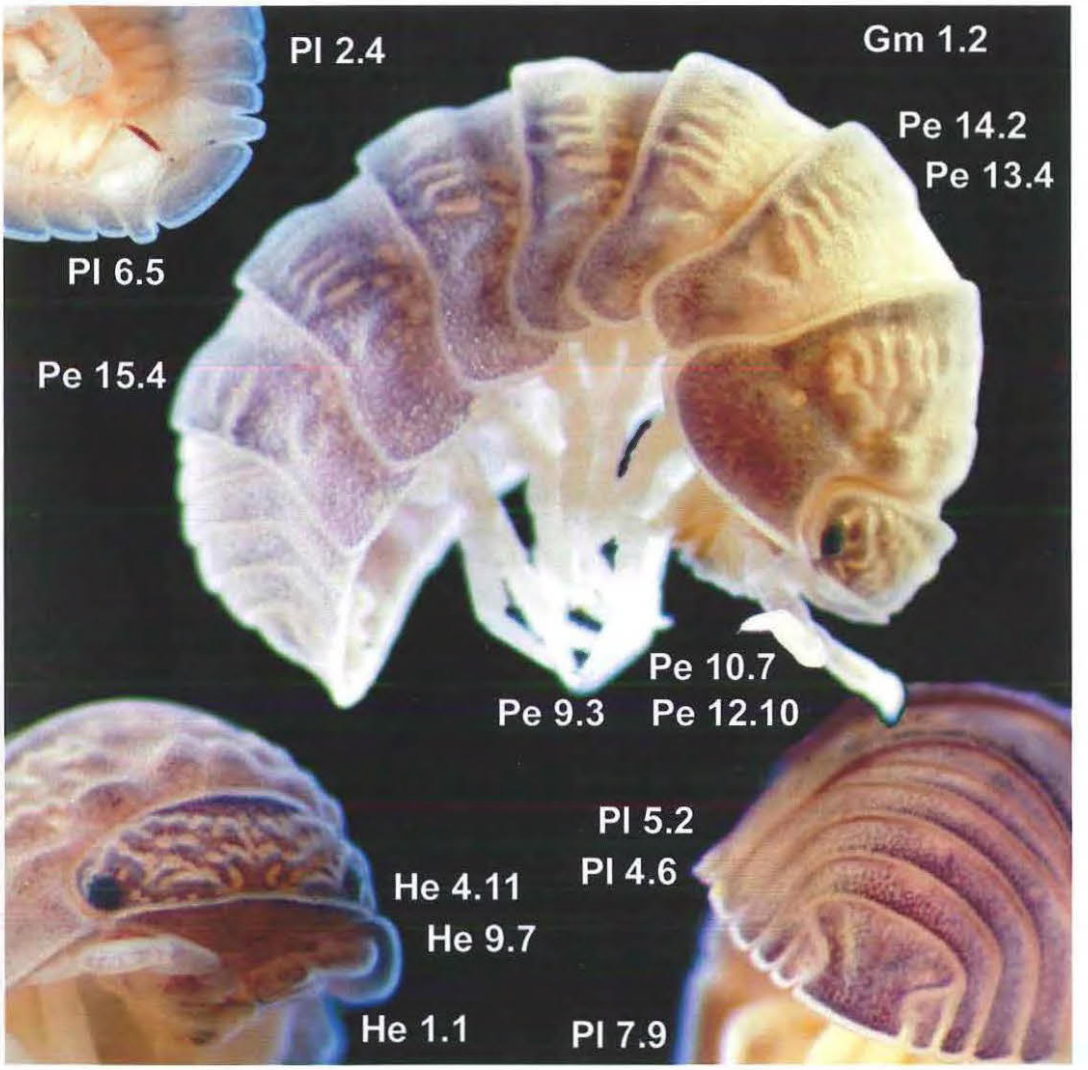


Plate 3.92. <u>Acanthodillo</u> **species 5 from Narlingup Nature Reserve (C30727) (length 5 mm).**

3.17.5. GENUS CUBARIS BRANDT

Diagnosis: The following diagnosis is abbreviated and modified from Green (1961, p.329). Frontal ridge simple and without modification of any kind. Second antenna slender with greater part of it protruding from head. Posterior angle of pereonal epimeron 1 entire, not cleft. Lobe on under surface of pereonal epimeron 1 small, not visible in lateral view and well separated from lateral border. Pereonal epimeron 1 without ventral groove (sulcus marginali). Pleopods occupy considerably more than one-third width of pleon. Telson either constricted medially or not constricted, dorsal surface without keel and the posterior border is bluntly rounded. Exopodites of pleopods all with pleopodal lungs. Uropod protopodites longer than wide and with exopodite inserted on dorsal surface close to, but removed from, inner border. Inner border of protopodite incurved but not angularly indented near insertion of protopodite.

Remarks: Of all the species described in this subsection, Cubaris species 1 displays the lobes on the undersurface of pereonal epimeron that are the smallest and most separated from the lateral border. In the other three species the lobes are larger and approach the lateral border of pereonal epimeron 1. They should probably be excluded from Cubaris sensu Green (1961). However, the problems with this genus were outlined in Subsection 3.2.4. Given that the genus is already recognised as a heterogeneous group defined by symplesiomorphic characters (Schmalfuss, 1983) they are included in this section because, apart from the larger endolobes, they are consistent with the other characters given by Green (1961). A review of the genus Cubaris would benefit from the inclusion of these species.

The endolobes of pereonal epimeron 1 and 2 of Cubaris species 1 are illustrated in Plate 3.93. There is a marked degree of separation from the lateral border.

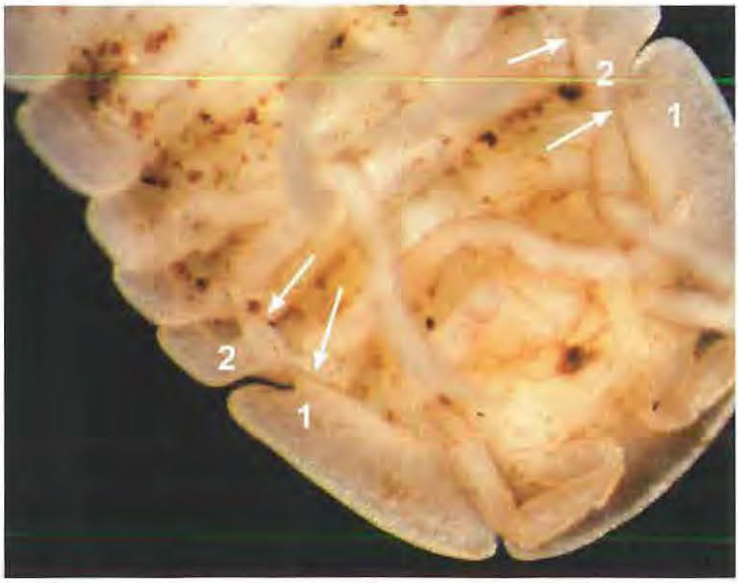


Plate 3.93. Cubarid endolobes on pereonal epimera 1 and 2. The lobes are small and well separated from the lateral epimeral border.

3.17.5.1. Cubaris species 1

Plate 3.1, Gm 1.3; Plate 3.17, Pe 1.21; Plate 3.25, Pe 9.4b; Plate 3.28, Pe. 12.6; Plate 3 93; Plate 3.94a, 3.94b.

MATERIAL EXAMINED: C30755, BINDOON SPRING, -31.4080°S 116 3670°E, JUDD, S., 09-10-98, G20; C30756, BINDOON SPRING, -31.4080°S 116 3670°E, JUDD, S., 09-10-98, G30; C31616, ARMADALE, -32 1500°S 116 0000°E, NORRIS, K. R., 12-05-34; C31617, APPLECROSS, -32.0167°S 115 8333°E, NICHOLLS COLLECTION?, ??-08-34, C32079, NORMAN ROAD, CARDUP, -32 2636°S 116.0036°E, WALDOCK, J. M., WEST, P. L. & LONGBOTTOM, A., 17-06-96, P3, C32080, NORMAN ROAD, CARDUP, -32 2689°S 116 0122°E, WALDOCK, J M , WEST, P. L & LONGBOTTOM, A., 17-06-96, P3

Diagnosis: Habitus roller/clinger. Highly concave. Eyes moderately developed and frontal ridge raised from dorsal surface of head. Pereonal epimeron 1 angled backwards and rounded with inner lobe very small, separated from lateral edge of epimeron and therefore not visible in lateral view. All other epimera nearly square and angled only slightly backwards. Pereonites with well-defined raised bumps with transverse row of bumps on posterior margin of each pereonite. Uropod protopodites long and tapering. Telson distinctly wider at distal margin than midpoint, with two bumps near anterior border and lateral margins highly incurved.

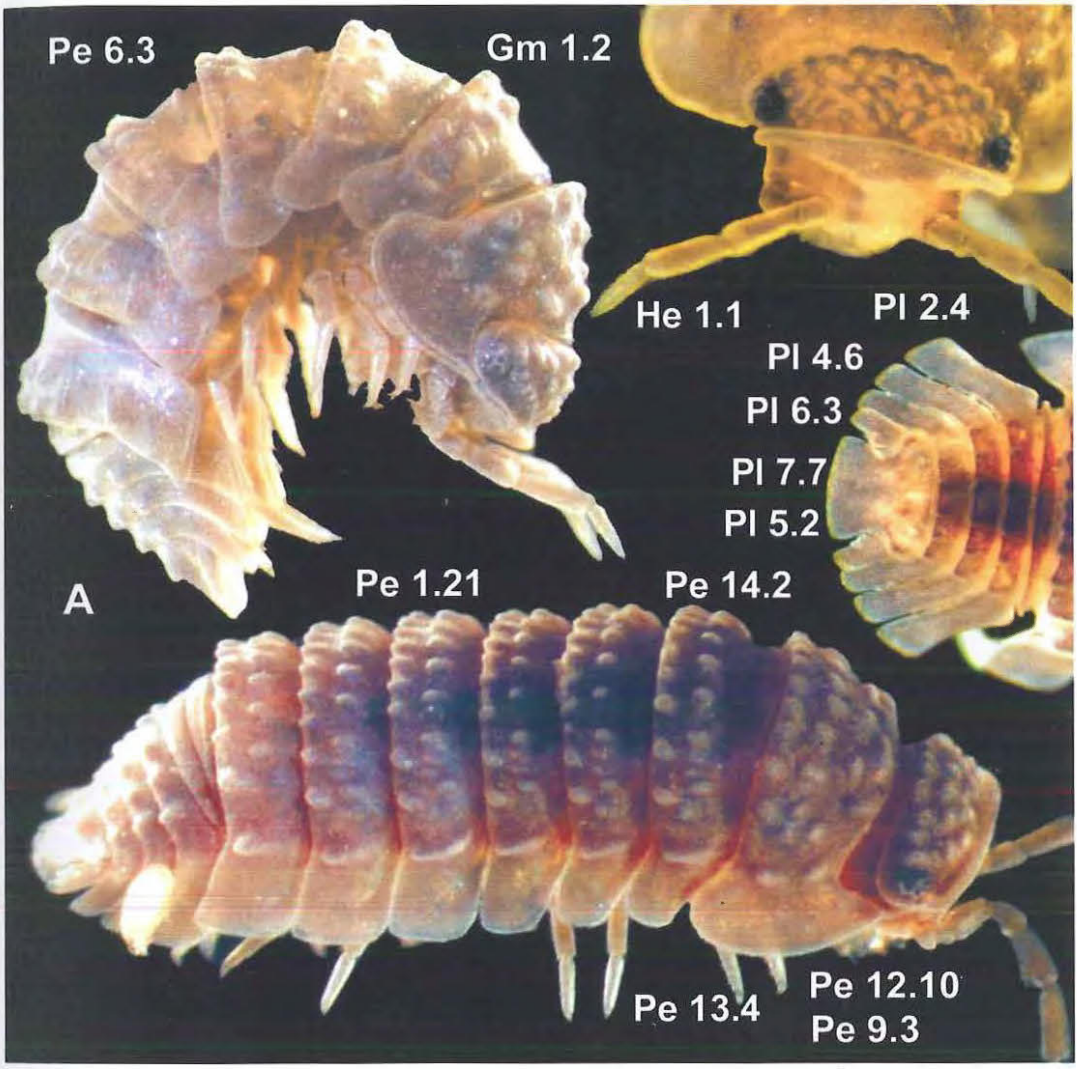


Plate 3.94a. Cubaris species 1 from Norman Road, Cardup (C32079) (length 7 mm).

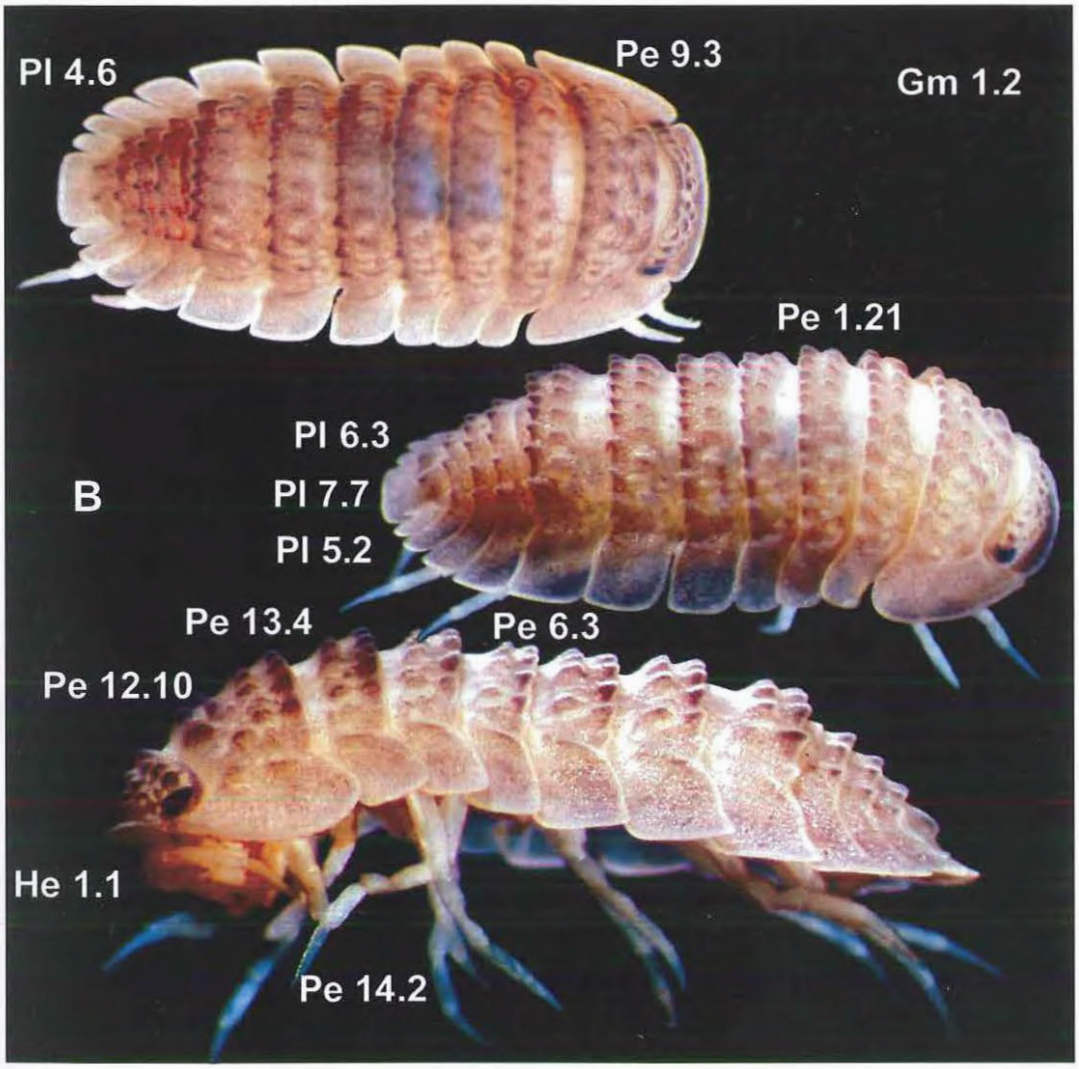


Plate 3.94b. Cubaris species 1 from Bindoon Spring Nature Reserve (C30755) (length 4.5 mm).

3.17.5.2. Cubaris species 2

Plate 3.17, Pe 1.22; Plate 3.40, Pl 7.7; Plate 3.95.

MATERIAL EXAMINED: C21090, BOLD PARK, -31 9583°S 115 7739°E, HUMPHREYS, W. F. ET AL , 15-03-87; C30743, NAMBUNG NATIONAL PARK, -30 5420°S 115.1430°E, JUDD, S , 15-10-98, L20, C30744, NAMBUNG NATIONAL PARK, -30 5420°S 115 1430°E, JUDD S., 15-10-98, G40, C30745, NAMBUNG NATIONAL PARK, -30 5420°S 115 1430°E, JUDD, S., 15-10-98, G30; C31605, POINT PERON, -32 3000°S 115 7000°E, KRN, MES (NICHOLLS COLLN), 30-08-33, R1; C31606, LESUEUR NATIONAL PARK COCKLESHELL GULLY ROAD, -30 1356°S 115 1236°E, WALDOCK, J M., 30-09-00, G30; C32070, BOLD PARK, -31 9372°S 115 7639°E, HARVEY, M S & WALDOCK, J. M , 20-07-93, P3; C32071, BOLD PARK, -31.9364°S 115 7739°E, WALDOCK, J M ET AL , 24-09-93, P3, C32072, BOLD PARK, -31.9353°S 115 7750°E, HARVEY, M S & WALDOCK, J. M., 20-07-93, P3, C32073, BOLD PARK, -31 9364°S 115.7639°E, HARVEY, M. S. & WALDOCK, J M., 19-05-94, P3, C32074, BOLD PARK, -31 9364°S 115 7639°E, WALDOCK, J. M ET AL , 18-11-93, P3

Diagnosis: Habitus roller/clinger. Slightly concave. Eyes moderately developed and frontal ridge raised from dorsal surface of head. Inner lobe of pereonal epimeron 1 small, separated from lateral border and therefore not visible in lateral view. Pereonal epimeron 1 angled backward. Other pereonal epimera square in appearance. Pereonites with poorly defined raised bumps in longitudinal rows but without transverse row tubercles on the posterior edge of pereonites. Uropod protopodites long and tapering. Telson distinctly wider at distal margin than at midpoint and with two bumps near anterior border. Lateral margins of telson incurved.

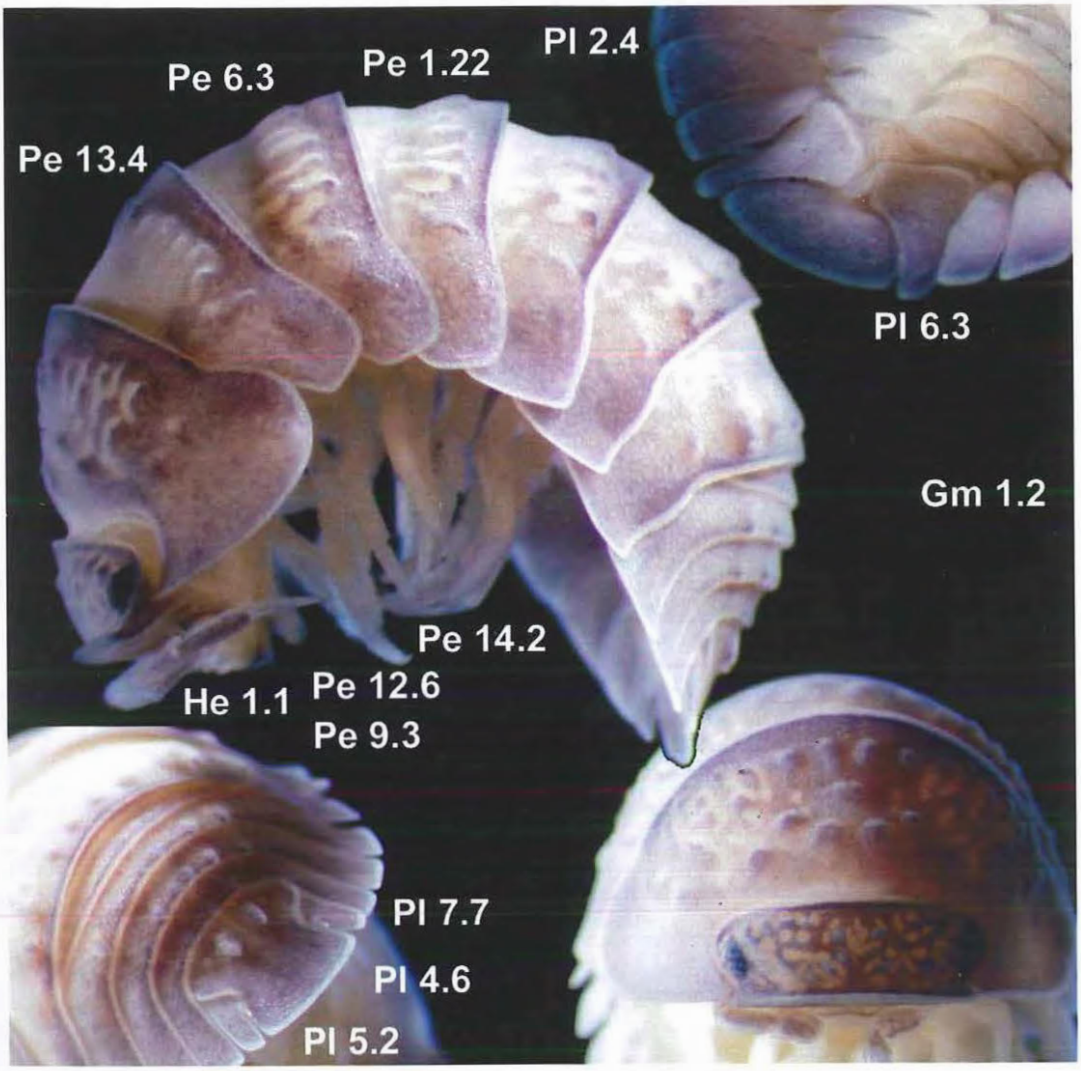


Plate 3.95. Cubaris species 2 from Nambung National Park (C30743) (length 6 mm).

3.17.5.3. Cubaris species 3

Plate 3.2, Gm 2.11; Plate 3.29, Pe 13.5; Plate 3.39, Pl 6.2; Plate 3.40, Pl 7.6; Plate 3.96.

Armadillidae sp. 5 Judd & Horwitz, 2003

MATERIAL EXAMINED C30721, RATE BLOCK, -34 8350°S 117.0070°E, JUDD, S , 01-09-99, L10; C30722, WEST CAPE HOWE NATIONAL PARK, -35 0820°S 117 6430°E, JUDD, S., 17-12-98, B10; C30723, WALPOLE NORNALUP NATIONAL PARK TINGLEWOOD, -35 0030°S 116 6380°E, JUDD, S., 07-01-99, B10; C30724, WALPOLE NORNALUP NATIONAL PARK TINGLEWOOD, -35 0030°S 116.6380°E, JUDD, S , 07-01-99, L10; C30725/6, SHANNON NATIONAL PARK (FISH CREEK ROAD), -34 6250°S 116 4370°E, JUDD, S., 27-01-99, B10, C31588, FRANKLAND RIVER, -35 0000°S 116.8167°E, NICHOLLS COLLECTION, 02-12-25, G30, C31589, WEST CAPE HOWE NATIONAL PARK, S OF TORBAY HILL NR SOUTH ROAD, -35 0833°S 117 6333°E, HARVEY, M. S. & WALDOCK, J. M., 27-03-93, B10, C31590, SWARBRICK'S TRACK VIA ALBANY, -35 0000°S 116 8167°E, NICHOLLS COLLECTION, 03-01-33, G30, C31591, PEMBERTON EASTBROOK, -34 4000°S 116 1000°E, MAIN, B. Y., 21-08-56, C31592, SHANNON RIVER NELSON, -34 7167°S 116 3500°E, HARVEY, M S & BLOSFELDS, M. E., 18-02-90, B10; C31593, WALPOLE INLET PENINSULAR, -34 9833°S 116 7167°E, NICHOLLS COLLECTION, 06-01-33; C31594, SWARBRICKS HILL BEHIND, -35 0000°S 116 8167°E, NICHOLLS COLLECTION, 24-11-39; C31595, WALPOLE ROAD TO WALPOLE NEAR LAND LEACH GULLY, -34 9833°S 116.7167°E, NICHOLLS COLLECTION, 23-11-38; C31596, SWARBRICK'S TRACK VIA ALBANY, -35 0000°S 116 8167°E, NICHOLLS COLLECTION, 03-01-33; C31597, SWARBRICK'S TRACK VIA ALBANY, -35 0000°S 116 8167°E, NICHOLLS COLLECTION, 04-01-33, B10, C31598, WALPOLE INLET CAMP SITE, -34 9833°S 116.7167°E, NICHOLLS COLLECTION, 30-12-32, B10, C31599, NORNALUP, -35.0000°S 116 8167°E, , ??-??-??; C31600, FRANKLAND RIVER, -35.0000°S 116 8167°E, NICHOLLS COLLECTION, 11-01-38; C31601, WALPOLE NORNALUP NATIONAL PARK KARRI FOREST, -34 9833°S 116.7083°E, VAN HEURCK, P. ET AL , 13-05-97, B40

Diagnosis: Habitus roller. Slightly concave. Eye well-developed and frontal ridge raised slightly from dorsal surface of head. Epimeron 1 angled backwards with inner lobe very small and therefore not visible in lateral view. Other pereonal epimera with rounded appearance. Animal with smooth pereonites, cream and pale brown in colour. Uropod protopodites short and not tapering. Telson broad but quite short and barely wider at distal margin than midpoint.

Remarks: This species differs from the other three Cubaris species in having a flatter frontal ridge and a telson, with a shorter and more angular inner border. This telson is not typical of Cubaris and needs further evaluation. However, the nature of the lobes of the first pereonal epimeron suggest that it most closely resembles Cubaris and excludes it from other genera of Armadillidae described here

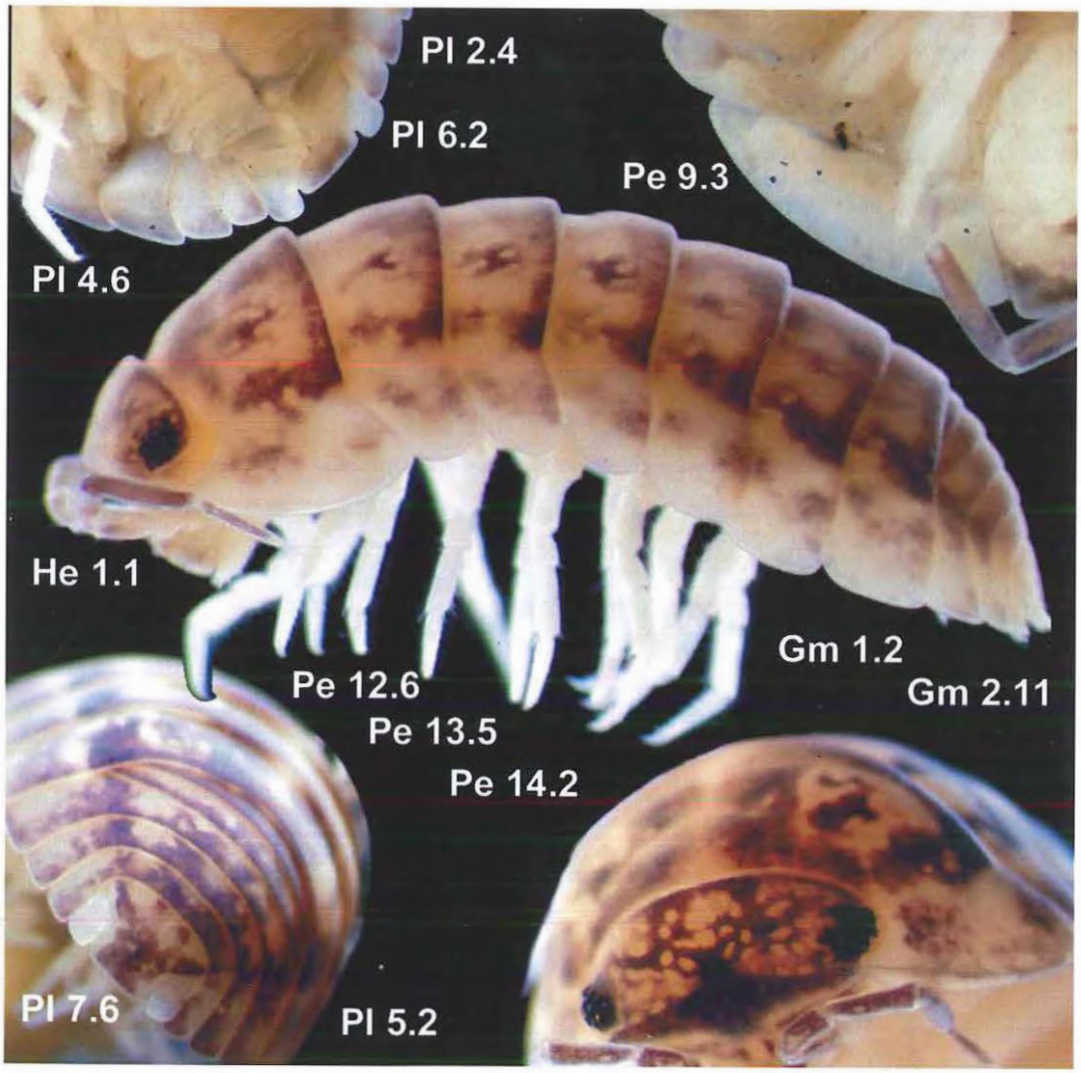


Plate 3.96. Cubaris **species 3 from West Cape Howe National Park (C30722) (length 6 mm).**

3.17.5.4. Cubaris species 4

Plate 3.13, Pe 9.6; Plate 3 14, He 11 1; Plate 3 15, He 11.1; Plate 3 25, Pe 9.4a; Plate 3.28, Pe 12.5; Plate 3 29, Pe 13 4, Plate 3.37, Pl 4.6; Plate 3.39, Pl 6 3, Plate 3 40, Pl 7 8, Plate 3 97.

MATERIAL EXAMINED C18422 TWO PEOPLES BAY, -34 9833°S 118 1667°E, NICHOLLS COLLECTION, ??-??-??, R1. C31609, TORNDIRRUP NATIONAL PARK SHARP POINT -35 1100°S 117 8667°E, HARVEY M S & WALDOCK, J M, 26-03-93, R4. C31610, TWO PEOPLES BAY, -34 9833°S 118 1667°E, NICHOLLS COLLECTION, ??-??-35

Diagnosis. Habitus roller. Slightly concave. Eye well-developed. Frontal ridge almost straight and projecting well above dorsal surface of head. Clypeal lobes very broad and long Pereonal epimeron 1 without ventral groove (sulcus marginali). Posterior margin of pereonal epimeron 1 produced strongly backwards. Inner lobe separated from lateral margin of epimera but sub-equal in length with posterior lateral border of pereonal epimeron 1 Therefore, inner lobe sometimes visible in lateral view. Pereonites smooth. Head without well defined bumps behind each eye. Uropods long and tapering. Telson hourglass shaped with rounded appearance and distal margin much wider than midpoint.

Remarks: The angle of the central photograph in Plate 3.93 implies that the inner lobe of pereonal epimeron 1 is clearly visible. This is not the case in a perfectly lateral view.

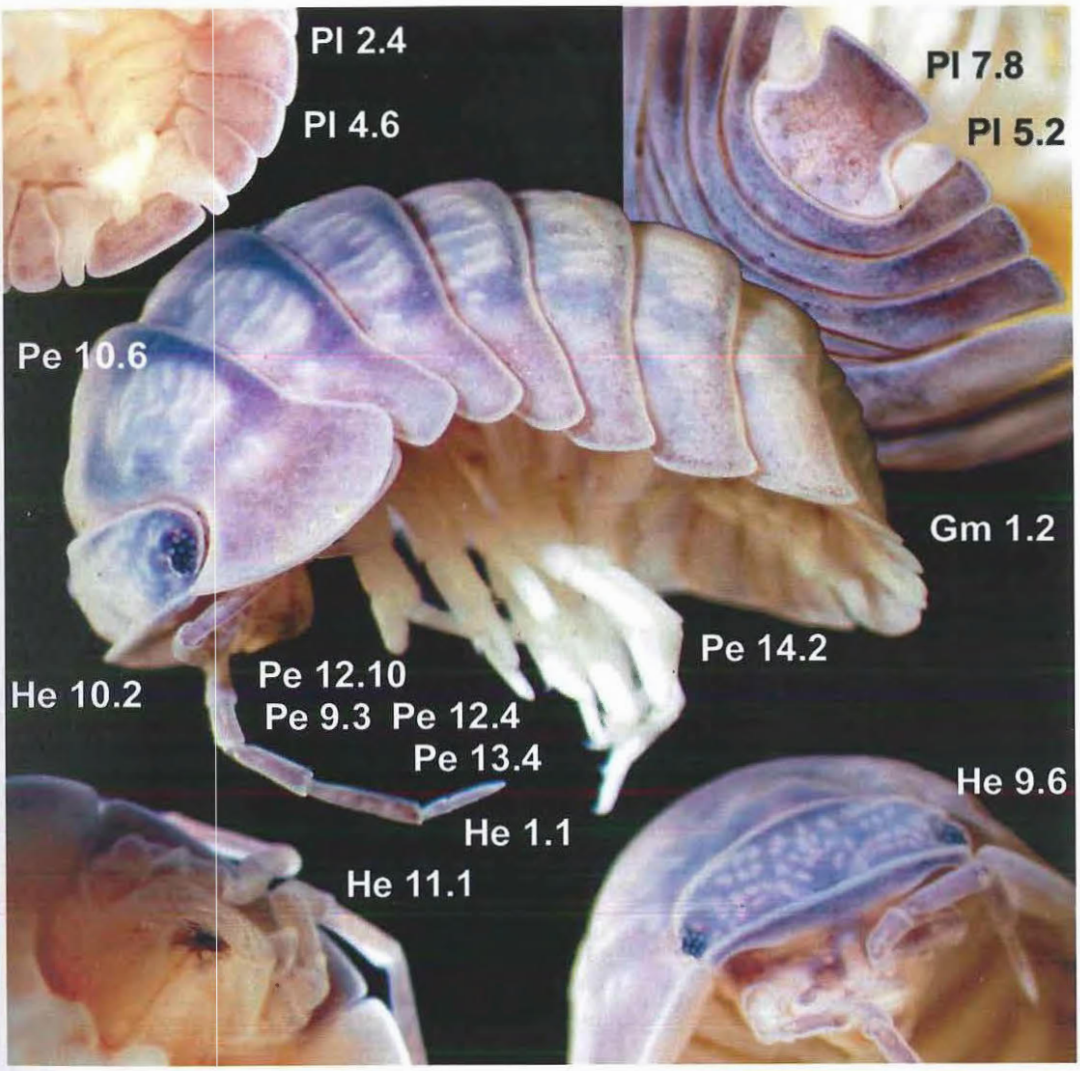


Plate 3.97. <u>Cubaris</u> **species 4 from Sharp Point, Torndirrup National Park (C31609) (length 9 mm).**

3.17.6 BUDDELUNDIA MICHAELSEN

Diagnosis: Highly convex. Exopodites of pleopods 1-4 are grooved and interlock and exopodite 5 is covered by 4. Pleopodal lungs are present only in exopodites 1-4. Telson hourglass-shaped. Pereonal epimeron 1 sometimes with a longitudinal furrow (sulcus arcuatus) running parallel to lateral margin.

TYPE MATERIAL EXAMINED BUT NOT FOUND IN THE REGION C382, BUDDELUNDIA SUBINERMIS BUDDE-LUND, 1912, SYNTYPE, ERADU, HAMBURG EXPEDITION STN 80, 28° 42'S, 115° 02'E, WA, 13-07-05. C386, BUDDELUNDIA LAEVIGATUS BUDDE-LUND, 1912, SYNTYPE, DAY DAWN, HAMBURG EXPEDITION STN 76, 27°28'S, 117° 52'E, WA, 09-07-05. C387, BUDDELUNDIA BINOTATUS BUDDE-LUND, 1912, SYNTYPE, BOORABBIN, HAMBURG EXPEDITION STN 95, WA, 03-07-05. C391, BUDDELUNDIA BIPARTITUS BUDDE-LUND, 1912, SYNTYPE, BABA HEAD, EDEL-LAND, HAMBURG EXPEDITION STN 69, WA, 07-09-05. C395, BUDDELUNDIA CALLOSUS BUDDE-LUND, 1912, SYNTYPE, NORTHAMPTON, STN 71, WA, 15-07-05. C398, BUDDELUNDIA SULCATUS BUDDE-LUND, 1912 SYNTYPE, ERADU, HAMBURG EXPEDITION STN 80, 28° 42'S, 115° 02'E, 13-07-05.

UNDETERMINED MATERIAL EXAMINED C1683/8, DANDARAGAN, -30 6667°S 115 7000°E, GLAUERT, L., ??-??-25. C30757, BINDOON SPRING, -31 4080°S 116 3670°E, JUDD, S., 09-10-98, G40. C30758, JULIMAR CONSERVATION PARK, -31 3950°S 116 2950°E, JUDD, S., 09-10-98, L42. C30760, JINGALUP NATURE RESERVE, -34 0130°S 117 0130°E, JUDD, S., 29-10-98, L42. C30895, BENGER SWAMP NATURE RESERVE, -33 1780°S 115 8330°E, JUDD, S., 25-11-98, L10. C30907, WANNAMAL LAKES NATURE RESERVE, -31 0750°S 116 0470°E, JUDD, S., 11-10-98, G30. C31768, BRUNSWICK FLATLAND AT THE FOOT OF DARLING RANGE, -33 2500°S 115 8330°E, HAMBURG EXPEDITION, 07-10-05[11].

3.17.6.1. Buddelundia inaequalis Budde-Lund, 1912

Plate 3.1, Gm 1.2; Plate 3.28, Pe 12 13; Plate 3 98.

Armadillo (Buddelundia) inaequalis Budde-Lund, 1912

Buddelundia cinerascens Bunn and Green, 1982

Buddelundia inaequalis Judd & Horwitz, 2003

TYPE MATERIAL EXAMINED C377, SYNTYPE, FREMANTLE, OBELISK-HUGEL, HAMBURG EXPEDITION STN 119, WA, 20-05-05

MATERIAL EXAMINED C1664, COTTESLOE, -32 0000°S 115 7500°E, GLAUERT, L., ??-??-25. C1681, DANDARAGAN, -30 6667°S 115 7000°E, GLAUERT, L., ??-??-25. C2068/72, ROTTNEST ISLAND, BATHURST POINT, -32 0000°S 115 5500°E, GLAUERT, L., ??-??-27. C2083/91, ROTTNEST ISLAND MT HERSCHELL, -32 0000°S 115 5000°E, GLAUERT, L., ??-09-27. C2114/32, ROTTNEST ISLAND MT HERSCHELL, -32 0000°S 115 5000°E, GLAUERT, L., ??-??-27. C2141/48, ROTTNEST ISLAND LAKE HERSCHELL, -32 0000°S 115 5000°E, GLAUERT, L., ??-??-27. C2171/74, ROTTNEST ISLAND PADBURY'S FLAT, -32 0000°S 115 5000°E, GLAUERT, L., ??-??-27. C2177/79, ROTTNEST ISLAND LAKE BAGHDAD, -32 0000°S 115 5000°E, GLAUERT, L., ??-??-27. C2190/201, ROTTNEST ISLAND, POINT CLUNE, -31 9830°S 115 5170°E, GLAUERT, L., ??-??-27. C2235, ROTTNEST ISLAND NORTH POINT, -32 0000°S 115 5100°E, GLAUERT, L., ??-??-27. C2244/55, ROTTNEST ISLAND NORTH POINT, -32 0000°S 115 5100°E, GLAUERT, L., ??-09-27. C2259/63, ROTTNEST ISLAND BICKLEY SWAMP, -32 0000°S 115 5000°E, GLAUERT, L., ??-??-27. C2677/98, ROTTNEST ISLAND, POINT CLUNE, -31 9830°S 115 5170°E, GLAUERT, L., ??-??-28. C3465/71, SPEARWOOD, -32 1000°S 115 7833°E, GLAUERT, L., ??-08-29. C12904, ROTTNEST ISLAND JEANES LOOKOUT, -32 0000°S 115 5000°E, BUNN, S., 04-11-80, R1. C12905, ROTTNEST ISLAND ISLET 20, -32 0000°S 115 5000°E, BUNN, S., 06-05-80. C12906, ROTTNEST ISLAND ISLET 36, -32 0000°S 115 5000°E, BUNN, S., 07-05-80. C12907, ROTTNEST ISLAND ISLET 37, -32 0000°S 115 5000°E, BUNN, S., 07-05-80. C18401, ROTTNEST ISLAND MT HERSCHELL, -32 0000°S 115 5000°E., ??-??-??. C18407, NORTH BEACH, -31 8667°S 115 7500°E, NICHOLLS COLLECTION, 29-07-33. C30761/2, WEDGE ISLAND DU [illegible], -30 8410°S 115 2320°E, JUDD, S., 07-08-98, L10. C30763/65, NILGEN NATURE RESERVE TUKEY [illegible]ACK, -30 8730°S 115 3070°E, JUDD, S., 07-08-98, L10. C30766/7, SALT LAKE (NORTH OF JURIEN BAY), -30 1880°S 115 0200°E, JUDD, S., 14-10-98, S1. C31618, ROTTNEST ISLAND ISLANDS ADJACENT TO POINT PERON, -32 0000°S 115 5000°E, NORRIS, K. R. & M. I. S., 21-09-33, R1. C31619, ROTTNEST ISLAND LAKE BAGHDAD, -32 0000°S 115 5000°E, GLAUERT, L?, 13-04-39, R1. C31620, ROTTNEST ISLAND ISLANDS ADJACENT TO POINT PERON, -32 0000°S 115 5000°E, NORRIS, K. R. & M. I. S., 21-09-33, R1. C31621, ROTTNEST ISLAND SERPENTINE LAKE, -32 0000°S 115 5000°E, , ??-??-??. C31622, ROTTNEST ISLAND NE SIDE, -32 0000°S 115 5000°E, GLAUERT, L?, 13-04-39, R1. C31623, ROTTNEST ISLAND SERPENTINE LAKE NORTH SIDE, -32 0000°S

11 Determined as B. rugifrons by Budde-Lund but not included in type material (Jones, 1986). This presumably is the single (female) specimen collected from Brunswick (Budde-Lund, 1912 p. 29).

115.5000°E, , ??-??-??; C31624, POINT PERON, -32.3000°S 115.7000°E, KRN, MES (NICHOLLS COLLN), 30-08-33, R1; C31625, WATERMANS BAY 2 MILES NORTH, -31.8167°S 115.7500°E, COLLECTOR UNKNOWN, 27-11-32; C31626, ROTTNEST ISLAND LAKE HERSCHELL SMALL ISLAND SE, -32.0000°S 115.5000°E, GLAUERT, L?, 15-04-39, R1; C31627, PEPPERMINT GROVE, -32.0000°S 115.7667°E, KEIGHTLEY, R., ??-??-??; C31628, BOLD PARK, -31.9417°S 115.7639°E, HUMPHREYS, W. F. ET AL., ??-05-87; C31629, ROTTNEST ISLAND GEORDIE BAY, -32.0000°S 115.5167°E, HARVEY, M. S., 09-07-00, G30.

Diagnosis: Habitus roller. Frontal ridge flattened with secondary frontal development along entire length of frontal ridge. Clypeal lobes sharply pointed. Pereonite 1 with furrow parallel to lateral margin (sulcus arcuatus) approximately same width throughout entire length. Pereonite 1 irregularly bumpy. Posterior margin of pereonal epimeron 1 angled sharply backwards. Inner lobe of pereonal epimeron 1 much shorter than posterior lateral epimeron border.

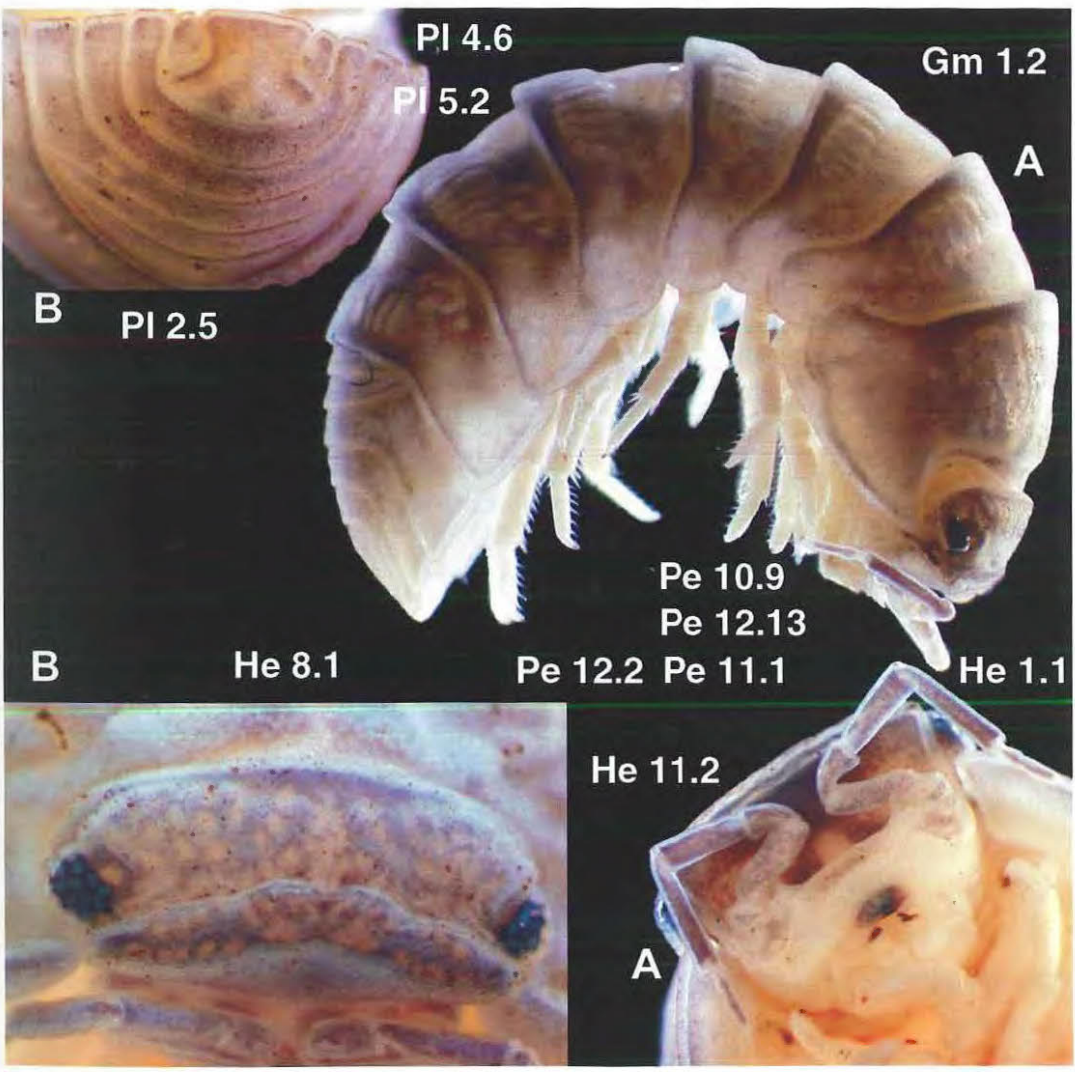


Plate 3.98. Buddelundia inaequalis **from (A) Geordie Bay, Rottnest Island (C31629) (length 12 mm) and (B) Nilgen Nature Reserve (C 30763).**

3.17.6.2. Buddelundia cinerascens Budde-Lund, 1912

Plate 3 12, He 8.1; Plate 3.15, He 11.2, Plate 3 26, Pe 10.9; Plate 3.27, Pe 11.1; Plate 3 28, Pe 12.14; Plate 3 99.

Armadillo (Buddelundia) cinerascens Budde-Lund, 1912

Buddelundia cinerascens Wahrberg, 1922

Buddelundia cinerascens Dalens, 1992

Buddelundia cinerascens Judd & Horwitz, 2003

TYPE MATERIAL EXAMINED C375, SYNTYPE, ROTTNEST ISLAND, HAMBURG EXPEDITION STN 121, WA, 06/13-09-05 (HEAD AND PEREONAL SEGMENT 1 MISSING)

MATERIAL EXAMINED C22367, CAREY BROOK AT VASSE HIGHWAY, -31 9667°S 115 8333°E, DELL, J , 29-06-95, C29703, NORTH BEACH, -31 8667°S 115 7500°E, NICHOLLS COLLECTION, 29-07-33, C30759, NAMBUNG NATIONAL PARK, PINNACLES, -30 6050°S 115 1600°E, JUDD, S , 15-10-98, S1, C30768, NILGEN NATURE RESERVE, -30 9730°S 115 3200°E, JUDD, S , 07-08-98, L10, C30769, NILGEN NATURE RESERVE, -30 9730°S 115 3200°E, JUDD, S , 07-08-98, S1, C30770, NILGEN NATURE RESERVE, -30 9730°S 115 3200°E, JUDD, S , 07-08-98, G40, C30771, YANCHEP NATIONAL PARK, -31 5200°S 115 6630°E, JUDD, S , 13-10-98, R4, C30772/3, DROVERS CAVE NATIONAL PARK, -30 2530°S 115 0870°E, JUDD, S , 14-10-98, R4, C30774, NAMBUNG NATIONAL PARK, -30 5420°S 115 1430°E, JUDD, S , 15-10-98, L20, C30775, NAMBUNG NATIONAL PARK, -30 5420°S 115 1430°E, JUDD, S., 15-10-98, G30, C30776, NAMBUNG NATIONAL PARK, -30 5420°S 115 1430°E, JUDD, S., 15-10-98, L40; C30777, NAMBUNG NATIONAL PARK, PINNACLES, -30 6050°S 115 1600°E, JUDD, S., 15-10-98, S1, C30778, NAMBUNG NATIONAL PARK LAKE THETIS, -30 5070°S 115 0820°E, JUDD, S., 16-10-98, S1, C30779, NAMBUNG NATIONAL PARK LAKE THETIS, -30 5070°S 115 0820°E, JUDD, S , 16-10-98, L70 C30780, NAMBUNG NATIONAL PARK LAKE THETIS, -30 5070°S 115 0820°E, JUDD, S , 16-10-98, R1 C30781, NAMBUNG NATIONAL PARK LAKE THETIS, -30 5070°S 115.0820°E, JUDD, S , 16-10-98, L10, C30782, MOORE RIVER STATE FOREST, -31 1400°S 115 4750°E, JUDD, S , 16-10-98, G30, C30783, MOORE RIVER STATE FOREST, -31 1400°S 115 4750°E, JUDD, S , 16-10-98, G40; C30784, MOORE RIVER NORTH BANK, -31 3530°S 115 5020°E, JUDD, S , 18-10-98, R1, C30785, MOORE RIVER NORTH BANK, -31 3530°S 115 5020°E, JUDD, S , 18-10-98, L30, C31630/1, WATERMANS BAY 2 MILES NORTH, -31 8167°S 115 7500°E, NICHOLLS COLLECTION, 27-11-32, C31632, CANNINGTON BOT RES , -32 0258°S 115 9828°E, HUMPHREYS, W F ET AL , 01-12-86; C31633, CANNINGTON BOT RES , -32 0247°S 115 9825°E, HUMPHREYS, W F ET AL , ??-05-87, C31634, CANNINGTON BOT RES , -32 0247°S 115 9831°E, HUMPHREYS, W F ET AL , 23-02-87, C31635, MULLALOO 3 KM N -31 8000°S 115 7333°E, CHAPMAN, A , 02-01-78, P1, C31636, LANCELIN 1 KM NE, -31 0264°S 115 3617°E, WEST, P L & TEALE, R , 05-04-00, P1, C31637, RANGER CAVE NAMBUNG NATIONAL PARK, -30 5330°S 115 1500°E, LOWRY, J , 23-02-74, C31638, SUPER CAVE NAMBUNG NATIONAL PARK, -30 5330°S 115 1500°E, LOWRY, J , 20-08-73, C32082, TRIGG DUNE BUSH, -31 8792°S 115 7547°E, HARVEY, M S & WALDOCK, J M , 28-11-95, P3, C32083, TRIGG DUNE BUSH, -31 8792°S 115 7547°E, HARVEY, M S & WALDOCK, J M , 29-01-96, P3, C32084, TRIGG DUNE BUSH, -31 8792°S 115 7547°E, WALDOCK, J M , WEST, P L & WHEELER, A , 28-03-96, P3, C32085, HEPBURN HEIGHTS, -31 8186°S 115 7697°E, WALDOCK, J M & HARVEY, M S , 25-09-95, P3, C32086, HEPBURN HEIGHTS, -31 8186°S 115 7697°E, WALDOCK, J M & HARVEY, M S , 28-11-95, P3, C32087, HEPBURN HEIGHTS, -31 8186°S 115 7697°E, WALDOCK, J M & HARVEY, M S , 29-01-96, P3, C32088, HEPBURN HEIGHTS, -31 8186°S 115 7697°E, WALDOCK, J M & HARVEY, M S , 29-01-96, P3, C32089, HEPBURN HEIGHTS, -31 8183°S 115 7672°E, WALDOCK, J M & HARVEY, M S , 29-01-96, P3, C32090, HEPBURN HEIGHTS, -31 8183°S 115 7672°E, WALDOCK, J M & HARVEY, M S , 28-11-95, P3, C32091, HEPBURN HEIGHTS, -31 8183°S 115 7672°E, WALDOCK, J M & HARVEY, M S , 25-09-95, P3

Diagnosis: Habitus roller. Frontal ridge flattened with secondary frontal development along entire length of frontal ridge. Clypeal lobes sharply pointed. Pereonite 1 with furrow parallel to lateral margin (sulcus arcuatus) approximately the same width throughout its entire length. Pereonites predominantly smooth. Posterior margin of pereonal epimeron 1 angled backwards. Inner lobe of pereonal epimeron 1 equal to or longer than posterior lateral epimeron border.

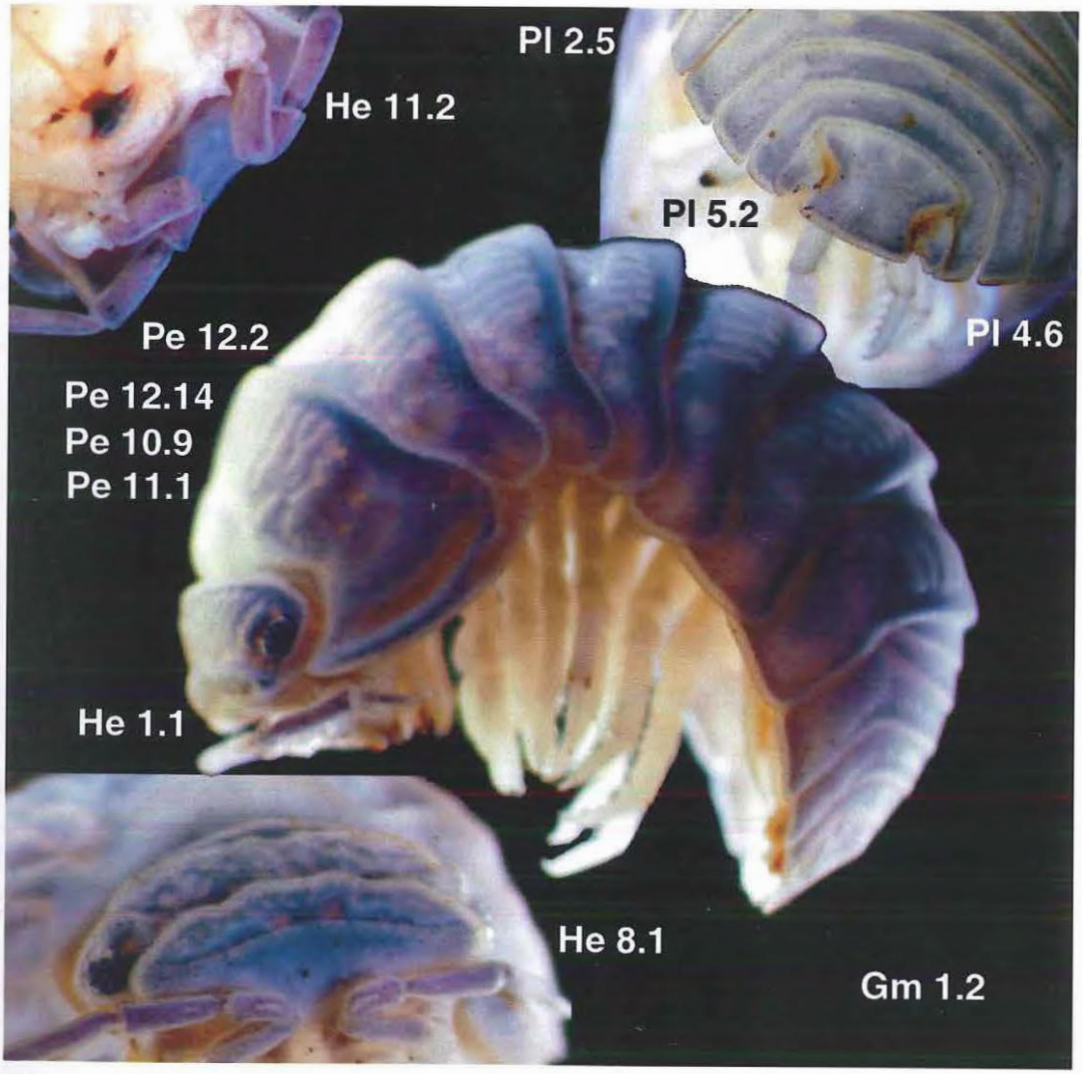


Plate 3.99. Buddelundia cinerascens **from Drovers Cave National Park (C 30772) (length 12 mm).**

3.17.6.3. Buddelundia species 1

Plate 3.15, He 11.3; Plate 3.17, Pe 1.25; Plate 3.26, Pe 10.10; Plate 3.100

MATERIAL EXAMINED: C2596/7, SERPENTINE, -32.3667°S 115.9667°E, GLAUERT, L., ??-??-28.

Diagnosis: Habitus roller. Secondary frontal development along prominent along entire length of frontal ridge. Eyes moderately developed, clypeal lobes broad and slightly pointed. Pereonal epimeron 1 nearly straight. Pereonite 1 without furrow parallel to lateral margin (sulcus arcuatus). Pereonites with pronounced longitudinal bumps.

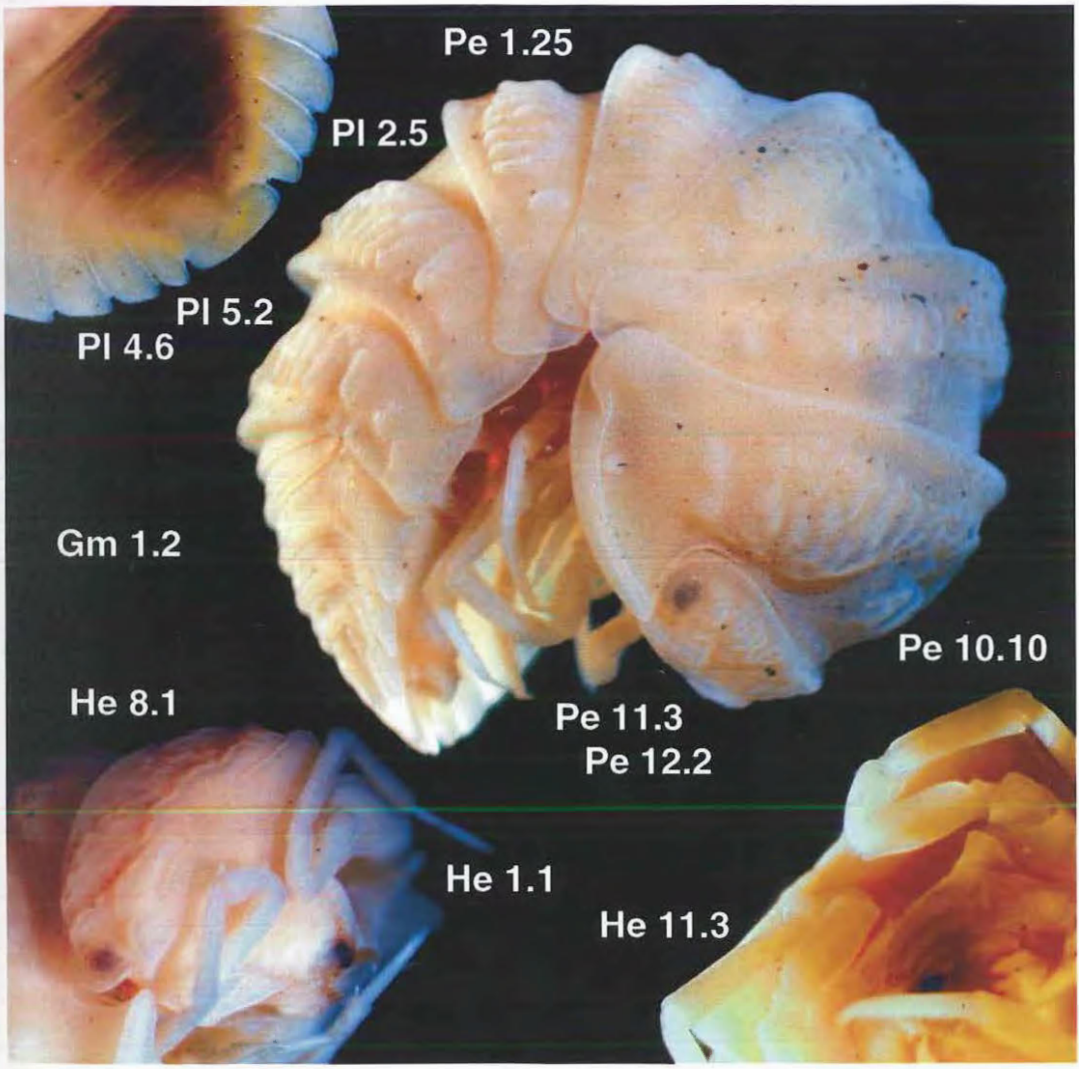


Plate 3.100. Buddelundia species 1 from Serpentine (C 2596) (length 12 mm).

3.17.6.4. Buddelundia species 2

Plate 3.26, Pe 10.11; Plate 3.101.

MATERIAL EXAMINED: C10826, NORTHAM, -31.6500°S 116.6667°E, EWB, 02-08-29; C18394, NORTHAM?, -31.6500°S 116.6667°E, EWB?, 02-08-29; C31765, CARTMETICUP, -33.5167°S 117.5333°E, ?, ??-??-??.

Diagnosis: Habitus roller. Eye well-developed and frontal ridge with secondary development continuous along its entire length. Pereonite 1 with furrow parallel to lateral margin (sulcus arcuatus). Clypeal lobes sub-rectangular. Pereonal epimeron 1 nearly straight with inner lobe and posterior lateral epimeron border sub-equal in length in lateral view. Dorsal surface of pereonites smooth. Telson wide but barely wider at distal margin than at mid-point.

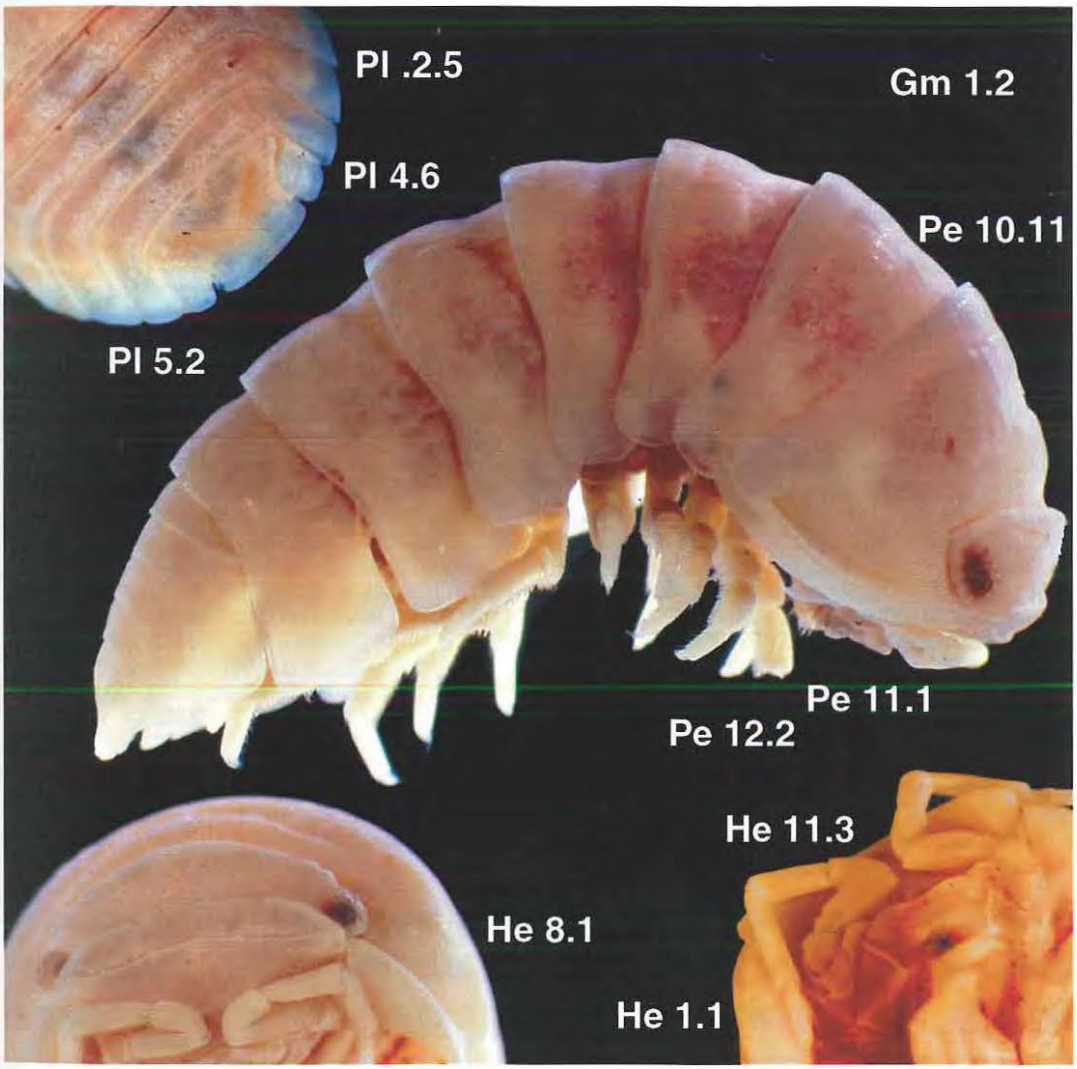


Plate 3.101. Buddelundia species 2 from Northam (C 18394) (length 12 mm).

3.17.6.5. Buddelundia opaca Budde-Lund, 1912

Plate 3.12, He 8.2; Plate 3.27, Pe 11.2; Plate 3.28, Pe 12.15; Plate 3.102.

Armadillo (Buddelundia) opacus Budde-Lund, 1912

Buddelundia opaca Vandel, 1973.

Buddelundia opaca Judd & Horwitz, 2003

TYPE MATERIAL EXAMINED. C379, SYNTYPE, GOOSEBERRY HILL, HAMBURG EXPEDITION STN 152, WA, 31-05-05

MATERIAL EXAMINED C783, DARLINGTON, -31 9167°S 116 0667°E, GLAUERT, L., 02-10-22; C784, DARLINGTON, -31 9167°S 116 0667°E, GLAUERT, L., 02-10-22, C1420, SWAN VIEW, -31 8833°S 116 0500°E, CLARKE, J., ??-12-23, C1682, DANDARAGAN, -30 6667°S 115 7000°E, GLAUERT, L., ??-??-25, C1949/53, BINDOON SOUTH, -31 3833°S 116 0833°E, GLAUERT, L., 14-05-27, C2564, DARLINGTON, -31 9167°S 116 0667°E, GLAUERT, L., ??-??-28, C2594/5, SERPENTINE, -32 3667°S 115 9667°E, GLAUERT, L., ??-??-28, C18395, ROLEYSTONE FLATSTONES, -32 1167°S 116 0667°E, NICHOLLS COLLECTION, 24-10-25, C18402, DANDARAGAN, -30.6667°S 115 7000°E, , ??-??-??; C18415, MUNDARING, -31 9000°S 116 1667°E, CLARKE, J., ??-??-??; C18416, SERPENTINE, -32.3667°S 115 9667°E, NICHOLLS COLLECTION, 26-09-26, C18420, LESMURDIE FALLS, -32 0167°S 116 0500°E, NICHOLLS COLLECTION, ??-??-??, C30813, GINGAGUP BROOK SCARP, -32.3150°S 116.0350°E, JUDD, S., 29-07-98, L30, C30814/5, CHITTERING LAKE RESERVE, -31 4180°S 116 0930°E, JUDD, S., 08-08-98, B40, C30816, CHITTERING LAKE RESERVE, -31 4180°S 116 0930°E, JUDD, S., 08-08-98, B30; C30817, JOHN FOREST NATIONAL PARK JANE BROOK, -31 8850°S 116 0900°E, JUDD, S., 11-08-98, R2; C30818, JOHN FOREST NATIONAL PARK JANE BROOK, -31 8850°S 116 0900°E, JUDD, S., 11-08-98, G20, C30819, JOHN FOREST NATIONAL PARK JANE BROOK, -31 8850°S 116 0900°E, JUDD, S., 11-08-98, R1, C30820, JOHN FOREST NATIONAL PARK (SCARP), -31 8900°S 116 0870°E, JUDD, S., 11-08-98, R1, C30821, JOHN FOREST NATIONAL PARK (SCARP), -31 8900°S 116 0870°E, JUDD, S., 11-08-98, L30; C30822, WALYUNGA NATIONAL PARK, -31 7320°S 116 0730°E, JUDD, S., 21-08-98, B30; C30823, WALYUNGA NATIONAL PARK, -31.7320°S 116 0730°E, JUDD, S., 21-08-98, L60; C30824/5, WALYUNGA NATIONAL PARK, -31.7320°S 116.0730°E, JUDD, S., 21-08-98, L10, C30826, JAM HILL NATURE RESERVE, -30 6860°S 115 8020°E, JUDD, S., 02-10-98, G40; C30827, JAM HILL NATURE RESERVE, -30 6860°S 115 8020°E, JUDD, S., 02-10-98, L20; C30828, BUNDARRA NATURE RESERVE, -30 9250°S 115 8250°E, JUDD, S., 04-10-98, L10, C30829, BUNDARRA NATURE RESERVE, -30 9250°S 115 8250°E, JUDD, S., 04-10-98, R2, C30830, BUNDARRA NATURE RESERVE, -30 9250°S 115 8250°E, JUDD, S., 04-10-98, G30, C30831, BUNDARRA NATURE RESERVE, -30 9250°S 115 8250°E, JUDD, S., 04-10-98, L41, C30832/4, BOONANARING NATURE RESERVE, -31.2330°S 115 9070°E, JUDD, S., 07-10-98, R3, C30835/7, SEVEN MILE WELL NATURE RESERVE, -31 0650°S 116 2020°E, JUDD, S., 11-10-98, R2; C30838, SEVEN MILE WELL NATURE RESERVE, -31 0650°S 116 2020°E, JUDD, S., 11-10-98, R1, C30839, MOUNT BYROOMANNING NR, -31 3730°S 116 1270°E, JUDD, S., 18-10-98, L10, C30840, MOUNT BYROOMANNING NR, -31.3730°S 116 1270°E, JUDD, S., 18-10-98, R2; C31686, MUNDARING SW71 HAVEL'S PLOT 136, -32.0000°S 116.3333°E, SPRINGETT, J. A., 05-11-71, C31687, DARLINGTON NR PERTH, -31 9167°S 116 0667°E, COLLECTOR UNKNOWN, 19-04-32; C31688, ARMADALE, -32 1500°S 116 0000°E, COLLECTOR UNKNOWN, 14-05-39; C31689, ARMADALE, -32.1500°S 116 0000°E, NORRIS, K. R., 12-05-34, C31690, MUNDARING SW71 HAVEL'S PLOT 136, -32 0000°S 116 3333°E, SPRINGETT, J. A., 05-11-71; C31691, MT DALE SOUTHERN SLOPE, -32 1333°S 116 3000°E, WALDOCK, J. M., 30-09-96, R2, C31692, MT LESUEUR 3 7 KM NNE, -30 1333°S 115 2000°E UWA, 11-07-89, G30, C31693, MT LESUEUR 5 KM NNE, -30 1333°S 115 2000°E, UWA, 09-07-89, R1, C31694, MT LESUEUR 5 KM NNE, -30 1333°S 115 2000°E, UWA, 10-07-89, R1, C31695, MT LESUEUR 6 5 KM NE, -30.1167°S 115 2333°E, UWA, 12-07-89, R1, C31696/7, MT LESUEUR 1 6 KM N, -30 1667°S 115 2000°E, UWA, 11-07-89, R1; C31698, MT LESUEUR 1 KM S, -30 1833°S 115 1833°E, UWA, 11-07-89, C31699, MT PERON 4 5 KM E, -30 1000°S 115 2000°E, UWA, 10-07-89, C31700, MT PERON 4 5 KM E, -30 1000°S 115 2000°E, UWA, 11-07-89, C31701, MT DALE WITHIN 300M OF SUMMIT, -32 1333°S 116 3000°E, JUDD, S., 29-03-00, L40, C31702, MT DALE WITHIN 300M OF SUMMIT, -32 1333°S 116 3000°E, JUDD, S., 29-03-00 G30.

Diagnosis: Habitus roller. Frontal ridge flattened with secondary frontal development confined to each end of frontal ridge. Pereonal epimeron 1 angled backwards with a deep and wide furrow parallel to lateral margin (sulcus arcuatus). Inner lobe of pereonal epimeron 1 longer than posterior lateral epimeron border in lateral view. Posterior lateral corner of epimeron 1 produced with a kink in thickened lateral margin of epimeron at junction of inner lobe.

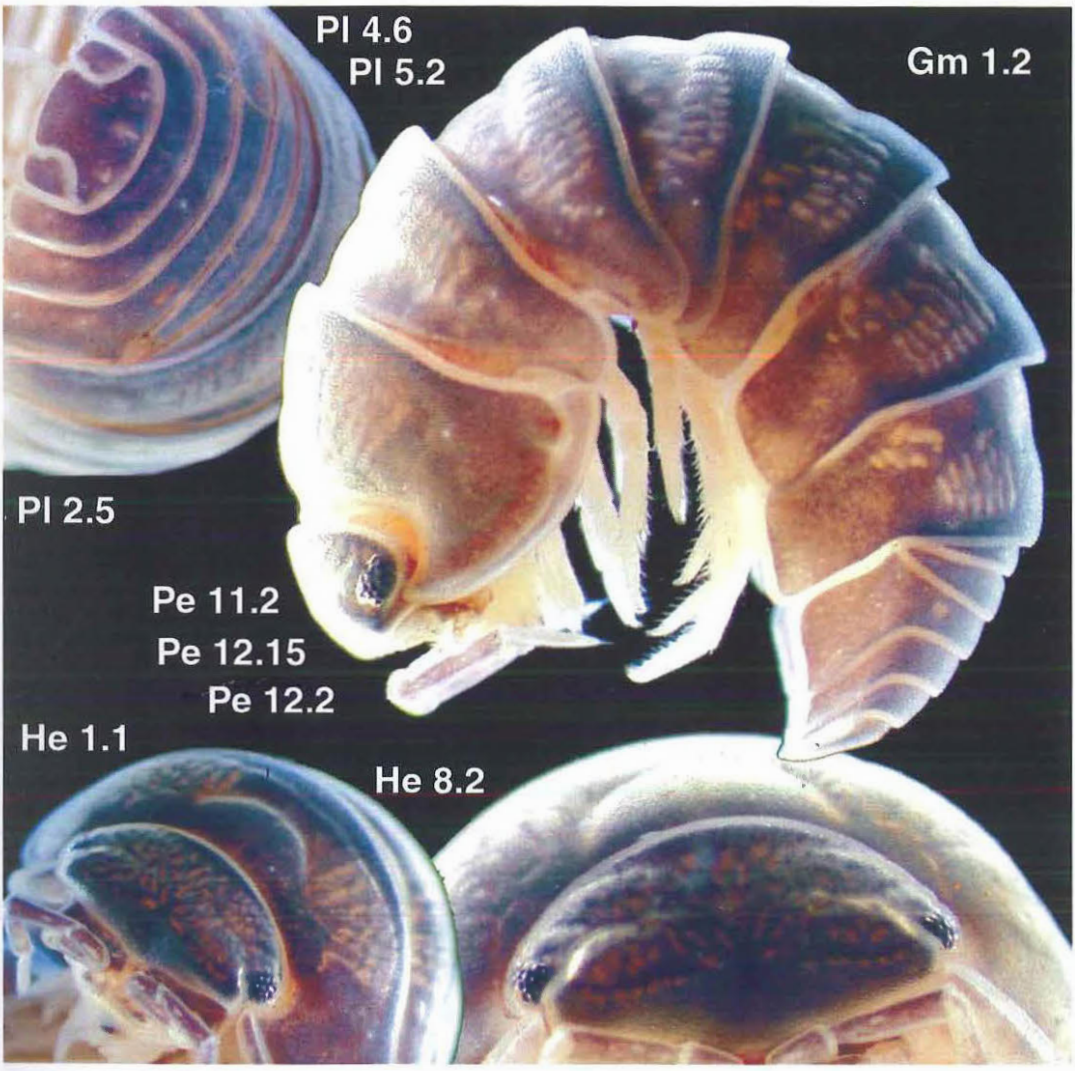


Plate 3.102. <u>Buddelundia</u> <u>opaca</u> **from the Darling Scarp at Gingagup Brook (C 30813) (length 12 mm).**

3.17.6.6. Buddelundia species 3

Plate 3.28, Pe 12.16; Plate 3.103

MATERIAL EXAMINED: C30931, WONGONDERRAH NATURE RESERVE, -30.5600°S 115.3580°E, JUDD, S., 15-10-98, G30; C31766/7, KINGS PARK, -31.9667°S 115.8333°E, DIXON, R. & KEYS, K., 25-03-92, P1.

Diagnosis: Habitus roller. Animal convex. Eye well-developed and clypeal lobes short and rounded. Frontal ridge flattened with secondary development confined to each end of frontal ridge. Pereonal epimeron 1 angled backwards and without furrow parallel to lateral margin (sulcus arcuatus). Inner lobe slightly shorter or equal to posterior lateral epimeron border in lateral view, posterior lateral epimeron border produced smoothly without kink at junction with inner lobe. Pereonites smooth.

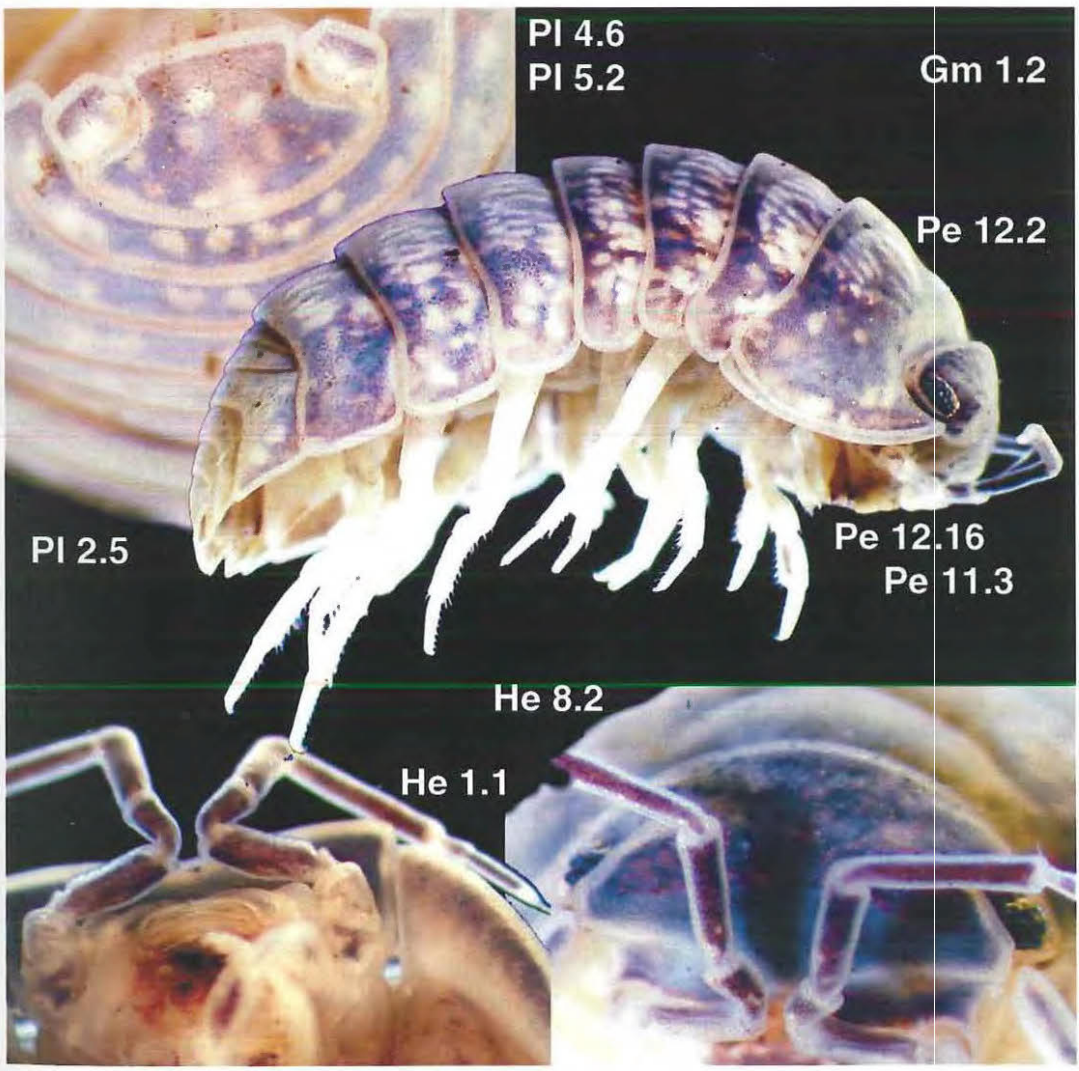


Plate 3.103. Buddelundia species 3 from Wongonderrah Nature Reserve (C30931) (length 10 mm).

3.17.6.7. Buddelundia species 4

Plate 3.9, He 5.6; Plate 3.13, He 9.8, Plate 3.20; Pe 4.4; Plate 3.40, Pl 7.12; Plate 3.104.

Buddelundia sp. 4 Judd & Horwitz, 2003

MATERIAL EXAMINED: C1335, CANNINGTON, -32 0167°S 115 9500°E, GLAUERT, L , ??-10-23, C30899, JOHN FOREST NATIONAL PARK (SCARP), -31 8900°S 116 0870°E, JUDD, S , 11-08-98, L30, C30900, JOHN FOREST NATIONAL PARK (SCARP), -31 8900°S 116 0870°E, JUDD, S , 11-08-98, B40, C30901, WALYUNGA NATIONAL PARK, -31.7320°S 116 0730°E, JUDD, S , 21-08-98, S1, C30902, WALYUNGA NATIONAL PARK, -31 7320°S 116 0730°E, JUDD, S , 21-08-98, L60, C30903, BINDOON SPRING, - 31 4080°S 116 3670°E, JUDD, S , 09-10-98, L10, C30904, BINDOON SPRING, -31 4080°S 116 3670°E, JUDD, S , 09-10-98, G30, C30905, JULIMAR CONSERVATION PARK, -31 3950°S 116 2950°E, JUDD, S , 09-10-98, L42, C30906, SEVEN MILE WELL NATURE RESERVE, -31 0650°S 116 2020°E, JUDD, S , 11-10-98, R2, C30908, WANNAMAL LAKES NATURE RESERVE, -31 0750°S 116 0470°E, JUDD, S , 11-10-98, R3; C30909, MOUNT BYROOMANNING NR, -31 3730°S 116 1270°E, JUDD, S , 18-10-98, R1, C30910, ST RONANS NATURE RESERVE, -31 8730°S 116 6400°E, JUDD, S , 21-10-98, L30, C30911, WANDOO CONSERVATION PARK, -32 0520°S 116 5450°E, JUDD, S , 22-10-98, G30, C31729, CANNINGTON, - 32 0167°S 115 9500°E, SOLOMON, M , 09-09-33, C31730, BULLSBROOK LAKE HOSKING, -31 6667°S 115 9833°E, , ??-??-??, C31731, MUNDARING AY77, -31 9000°S 116 1667°E, SPRINGETT, J A., 05-11-71, C31732, YORK 10 KM SW, -31 9500°S 116 5167°E, BANNISTER, J , 15-08-93, L10, C31733, KALAMUNDA, - 31 9667°S 116 0667°E, COLLECTOR UNKNOWN, 16-07-33, B40, C31734, MT DALE WITHIN 300M OF SUMMIT, -32 1333°S 116 3000°E, JUDD, S , 29-03-00, L10, C32216, BRICKWOOD RESERVE, CARDUP, - 32 2339°S 116 0019°E, WALDOCK, J. M , WEST, P. L & LONGBOTTOM, A., 17-06-96, P3, C32217, BRICKWOOD RESERVE, CARDUP, -32.2333°S 116 0006°E, WALDOCK, J M , WEST, P. L & LONGBOTTOM, A , 17-06-96, P3, C32218, BRICKWOOD RESERVE, CARDUP, -32 2311°S 116 0033°E, WALDOCK, J M , WEST, P L & LONGBOTTOM, A , 17-06-96, P3, C32219, RUSHTON ROAD, -32 0639°S 116.0189°E, WALDOCK, J M , WEST, P. L & LONGBOTTOM, A , 17-06-96, P3; C32220, RUSHTON ROAD, -32 0639°S 116 0189°E, WALDOCK, J M., WEST, P L & LONGBOTTOM, A , 17-06-96, P3, C32221, BUSHMEAD, -31 9322°S 116 0394°E, WALDOCK, J M , WEST, P L & LONGBOTTOM, A , 17-06-96, P3, C32222, BUSHMEAD, -31 9197°S 116 0169°E, WALDOCK, J M , WEST, P L & LONGBOTTOM, A, 17-06-96, P3; C32223, HARTFIELD PARK, -32 0000°S 115 9953°E, WALDOCK, J M., WEST, P L. & LONGBOTTOM, A , 17-06-96, P3, C32224, HARTFIELD PARK, -31 9978°S 115 9944°E, WALDOCK, J M., WEST, P L & LONGBOTTOM, A , 17-06-96, P3, C32225, NORMAN ROAD, CARDUP, -32 2636°S 116 0036°E, WALDOCK, J M , WEST, P L & LONGBOTTOM, A , 17-06-96, P3; C32226, NORMAN ROAD, CARDUP, -32 2672°S 116 0122°E, WALDOCK, J M., WEST, P. L & LONGBOTTOM, A , 17-06-96, P3, C32227, NORMAN ROAD, CARDUP, -32 2689°S 116 0122°E, WALDOCK, J M , WEST, P L & LONGBOTTOM, A , 17-06-96, P3, C32228, PERTH AIRPORT, -31 9767°S 115 9744°E, WALDOCK, J M. ET AL., 23-09-93, P3, C32229, PERTH AIRPORT, -31 9767°S 115 9744°E, WALDOCK, J M ET AL., 10-05-93, P3, C32230, PERTH AIRPORT, -31 9761°S 115 9736°E, WALDOCK, J M & HARVEY, M S , 19-05-94, P3; C32231, PERTH AIRPORT, -31 9675°S 115 9697°E, WALDOCK, J. M. & HARVEY, M. S , 24-06-93, P3; C32232, PERTH AIRPORT, -31 9675°S 115 9697°E, WALDOCK, J M ET AL , 18-11-93, P3; C32233, TALBOT ROAD RESERVE, -31 8736°S 116 0508°E, WALDOCK, J. M & HARVEY, M S , 18-03-94, P3; C32234, TALBOT ROAD RESERVE, -31 8736°S 116 0508°E, WALDOCK, J. M. ET AL., 18-11-93, P3, C32235, TALBOT ROAD RESERVE, -31 8736°S 116 0508°E, WALDOCK, J M., GOODSELL, J. & WEBB, J , 06-01-94, P3, C32236, TALBOT ROAD RESERVE, -31 8736°S 116 0508°E, WALDOCK, J M & HARVEY, M S , 28-07-93, P3

Diagnosis: Habitus roller. Animal dark brown with lighter cream patches. Frontal ridge raised slightly from dorsal surface of head at each end and formed by single well-defined line in smooth arc. No secondary frontal development behind primary frontal line but dorsal surface of head sometimes has 2 long bumps between eyes and frontal ridge. Eyes very well-developed. Pereonite 1 without deep furrow parallel to lateral margin (sulcus arcuatus). Dorsal surface smooth except for some shallow bumps on pereonite 1. Posterior margin of pereonal epimeron 1 curved backward and rounded. Pereonite 1 with shallow bumps. Telson short and not much wider at distal border than midpoint.

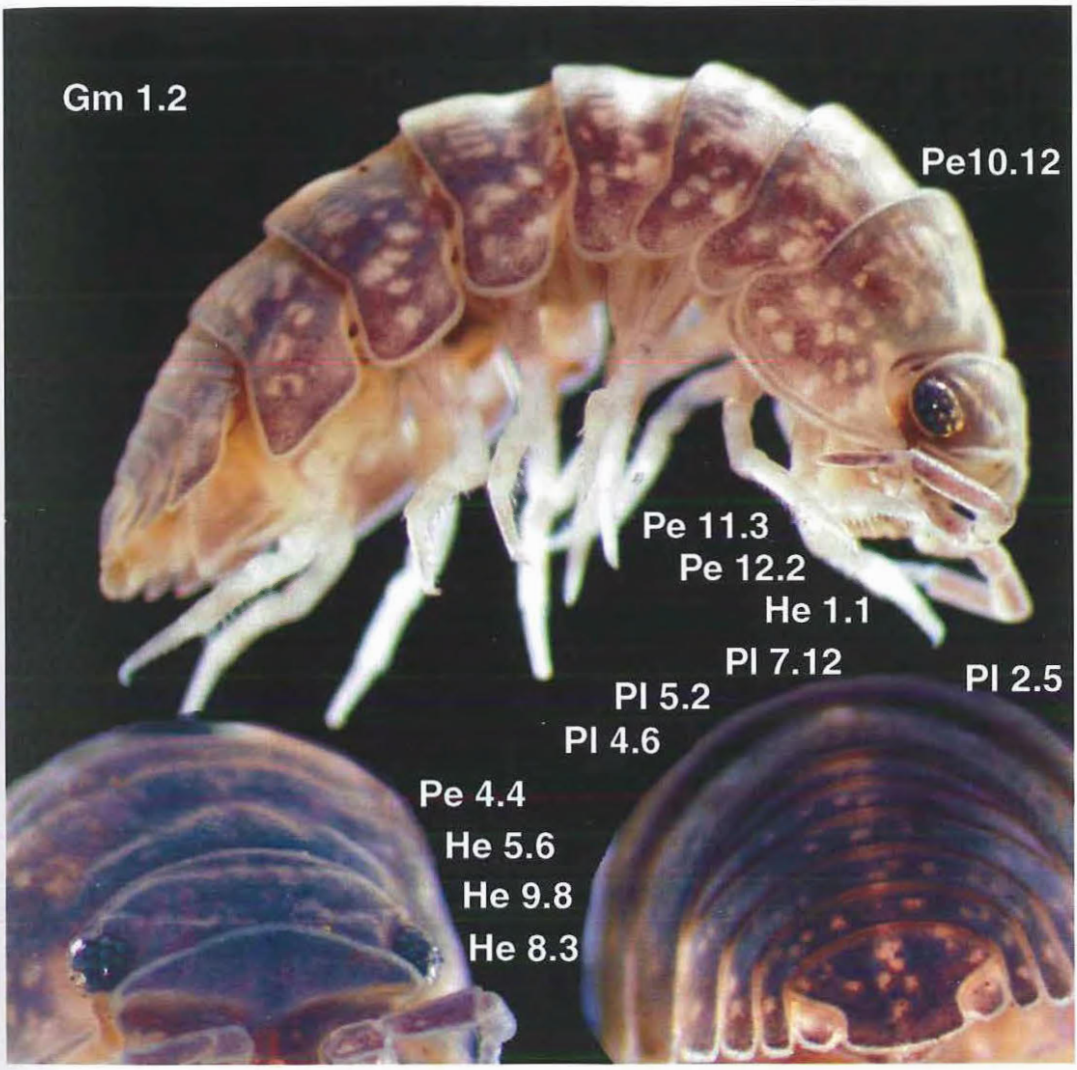


Plate 3.104. <u>Buddelundia</u> **species 4 from John Forest National Park (C 30899) (length 6 mm).**

3.17.6.8. Buddelundia species 5

Plate 3.2, Gm 2.12; Plate 3.13, He 9.9; Plate 3.26, Pe 10.12; Plate 3.27, Pe 11.3; Plate 3.40, Pl 7.13; Plate 3.105.

Buddelundia sp. 2 Judd & Horwitz, 2003

MATERIAL EXAMINED. C29716, MT COOKE, -32 4167°S 116 3000°E, WALDOCK, J. M. & CAR, C A., 28-11-91, P3; C30924, SCARP ROAD NEAR NORTH DANDALUP, -32.5600°S 116 0050°E, JUDD, S , 29-07-98, L10; C30925, SCARP ROAD NEAR NORTH DANDALUP, -32 5600°S 116.0050°E, JUDD, S., 29-07-98, B40, C30926/7, AMPHION FOREST BLOCK, -32 7920°S 116 1870°E, JUDD, S , 10-11-98, L10; C30928/9, LEPERS GULLY ROAD, -32.8470°S 116.1080°E, JUDD, S , 10-11-98, L10; C30930, LEPERS GULLY ROAD, -32 8470°S 116.1080°E, JUDD, S , 10-11-98, L20. C31757, MT COOKE, -32 4167°S 116 3000°E, HARVEY, M S & WALDOCK, J. M., 15-05-91, P3; C31758, MT COOKE, -32 4167°S 116.3000°E, HARVEY, M. S & WALDOCK, J M , 15-05-91; C31759, MT COOKF -32.4167°S 116.3000°E, HARVEY, M. S & WALDOCK, J. M , 16-06-91, P3, C31760, MT COOKE, -32 4167°S 116.3000°E, HARVEY, M. S. & WALDOCK, J. M , 15-05-91, P3, C31761, MT COOKE, -32 4167°S 116 3000°E, HARVEY, M S. & WALDOCK, J M , 19-09-91, P3, C31762, MT COOKE, -32.4167°S 116.3000°E, HARVEY, M. S & WALDOCK, J M , 19-09-91, L10; C31763/4, MT COOKE, -32 4167°S 116.3000°E, HARVEY, M. S. & WALDOCK, J. M., 25-02-92

Diagnosis: Habitus roller. Animal dark brown with very distinctive and conspicuous cream markings on pereonites. Frontal ridge relatively straight, forming less of arc, raised and rounded in the centre and depressed to some extent between eyes and central part. Eyes very well developed and clypeal lobes large and rounded. Epimera of pereonite 1 without deep furrow parallel to lateral margin (sulcus arcuatus) and with little thickening of lateral margin. Posterior margin of pereonal epimeron 1 curved backward and rounded. Pereonites smooth. Telson elongate, rounded and wider at distal border than at midpoint.

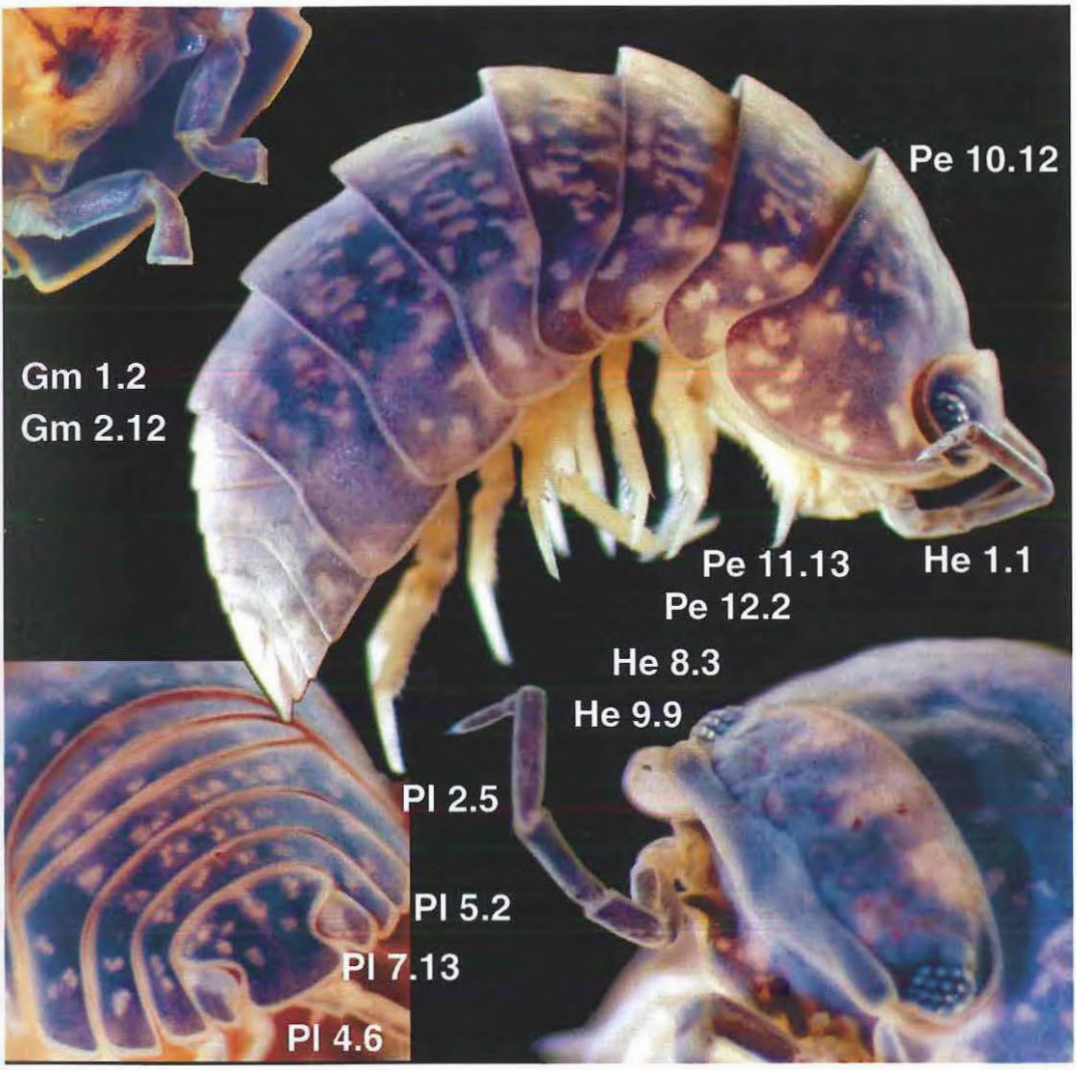


Plate 3.105. Buddelundia **species 5 from Amphion forest block (C 30926) (length 8 mm).**

3.17.6.9. Buddelundia species 6

Plate 3.2, Gm 2.13; Plate 3.13, He 9.10; Plate 3.40, Pl 7.14, Plate 3.106.

Buddelundia sp. 1 Judd & Horwitz, 2003

MATERIAL EXAMINED: C10821, SWARBRICK'S TRACK VIA ALBANY, -35 0000°S 116 8167°E, NICHOLLS COLLECTION, 04-01-33; C18419, WALPOLE INLET CAMP SITE, -34 9833°S 116 7333°E, NICHOLLS COLLECTION, 02-01-33; C30912/3, WARREN NATIONAL PARK TREAN BROOK, -34 4820°S 115 9250°E, JUDD, S., 13-08-98, B10; C30914, CLEAVE ROAD OFF SCOTT RD, -34 4180°S 115 7930°E, JUDD, S , 14-08-98, B40; C30915, BIG BROOK DAM FOREST, -34 4050°S 116.0270°E, JUDD, S , 15-08-98, L20; C30916, BIG BROOK DAM FOREST, -34.4050°S 116 0270°E, JUDD, S , 15-08-98, L10; C30917, BIG BROOK DAM FOREST, -34 4050°S 116 0270°E, JUDD, S , 15-08-98, B10; C30918, ELLIS CREEK ROAD, -33 9350°S 115 8820°E, JUDD, S., 03-12-98, L10; C30919, MARGARET RIVER CREEK, -33 9350°S 115 0650°E, JUDD, S , 10-12-98, B40; C30920, PORONGORUP NATIONAL PARK BOLGANUP DAM, -34 6700°S 117 8820°E, JUDD, S., 16-12-98, B10, C30921, PORONGORUP NATIONAL PARK BOLGANUP DAM, -34 6700°S 117 8820°E, JUDD, S., 18-12-98, L41, C30922, PORONGORUP NATIONAL PARK WANSBROUGH WALK, -34.6830°S 117 8480°E, JUDD, S , 16-12-98, B10, C30923, WALPOLE NORNALUP NATIONAL PARK TINGLEWOOD, -35.0030°S 116 6380°E, JUDD, S., 07-01-99, L10; C31740, PEMBERTON HV64 MARRI RD, -34 5000°S 116.0833°E, SPRINGETT, J. A., 03-12-71; C31741, PEMBERTON HL61 BIG BROOK, -34 2667°S 115.9333°E, SPRINGETT, J. A., ??-??-72, C31742, WALPOLE-NORNALUP NATIONAL PARK HILLTOP RD JUST BELOW COLLIER RD, -34.9833°S 116 7333°E, FRIEND, J A , 11-06-81, L40; C31743, NINDUP W OF WITCHCLIFFE, -34.0500°S 115.0500°E, WALDOCK, J. M , 06-02-93, L41; C31744/5, PORONGURUP NATIONAL PARK S END OF MILLINUP PASS, -34 7000°S 117 9000°E, HARVEY, M. S. & WALDOCK, J. M , 31-03-93, L10; C31746, PORONGURUP NATIONAL PARK TREE IN THE ROCK, -34.6833°S 117 8333°E, HARVEY, M S. & WALDOCK, J. M., 30-03-93; C31747, WALPOLE PENINSULAR, -34 9833°S 116 7167°E, NICHOLLS COLLECTION, ??-??-33; C31748/9, WALPOLE NORNALUP NATIONAL PARK, -34.9833°S 116 7167°E, WALLIS, N , ??-??-91; C31750, PORONGURUP NATIONAL PARK S END OF MILLINUP PASS, -34 6953°S 117 8975°E, HARVEY, M S., 02-09-96, P3; C31751, WELLINGTON MILL, -33 4500°S 115 9000°E, HARVEY, M. S , 10-05-97; C31752, WALPOLE NORNALUP NATIONAL PARK TINGLE CREEK FOREST, -34 9917°S 116 6583°E, VAN HEURCK, P ET AL , 20-05-97, G30; C31753, WALPOLE NORNALUP NATIONAL PARK TINGLE UPLAND FOREST, -34 9750°S 116 7917°E, VAN HEURCK, P ET AL., 15-05-97, L10; C31754, WALPOLE NORNALUP NATIONAL PARK TINGLE CREEK FOREST, -34 9750°S 116 7917°E, VAN HEURCK, P. ET AL , 14-05-97, B40; C31755, WALPOLE NORNALUP NATIONAL PARK TINGLE CREEK FOREST, -34 9750°S 116 7833°E, VAN HEURCK, P ET AL , 16-05-97, B40, C31756, PORONGURUP NATIONAL PARK S END OF MILLINUP PASS, -34 6953°S 117.8975°E, HARVEY, M S. & WALDOCK, J M., 28-04-86, B10

Diagnosis: Habitus roller. Animal light cream in colour with darker brown patches. Frontal ridge relatively straight, raised slightly at each end but without depressions either side of centre. Clypeal lobes large but of variable shape, sometimes elongate and pointed and sometimes rounded. Pereonite 1 without deep furrow parallel to lateral margin (sulcus arcuatus) and with little thickening of lateral margin. Posterior margin of pereonal epimeron 1 curved backward and rounded. Pereonites smooth. Telson greatly elongate, rounded and wider at distal border than midpoint.

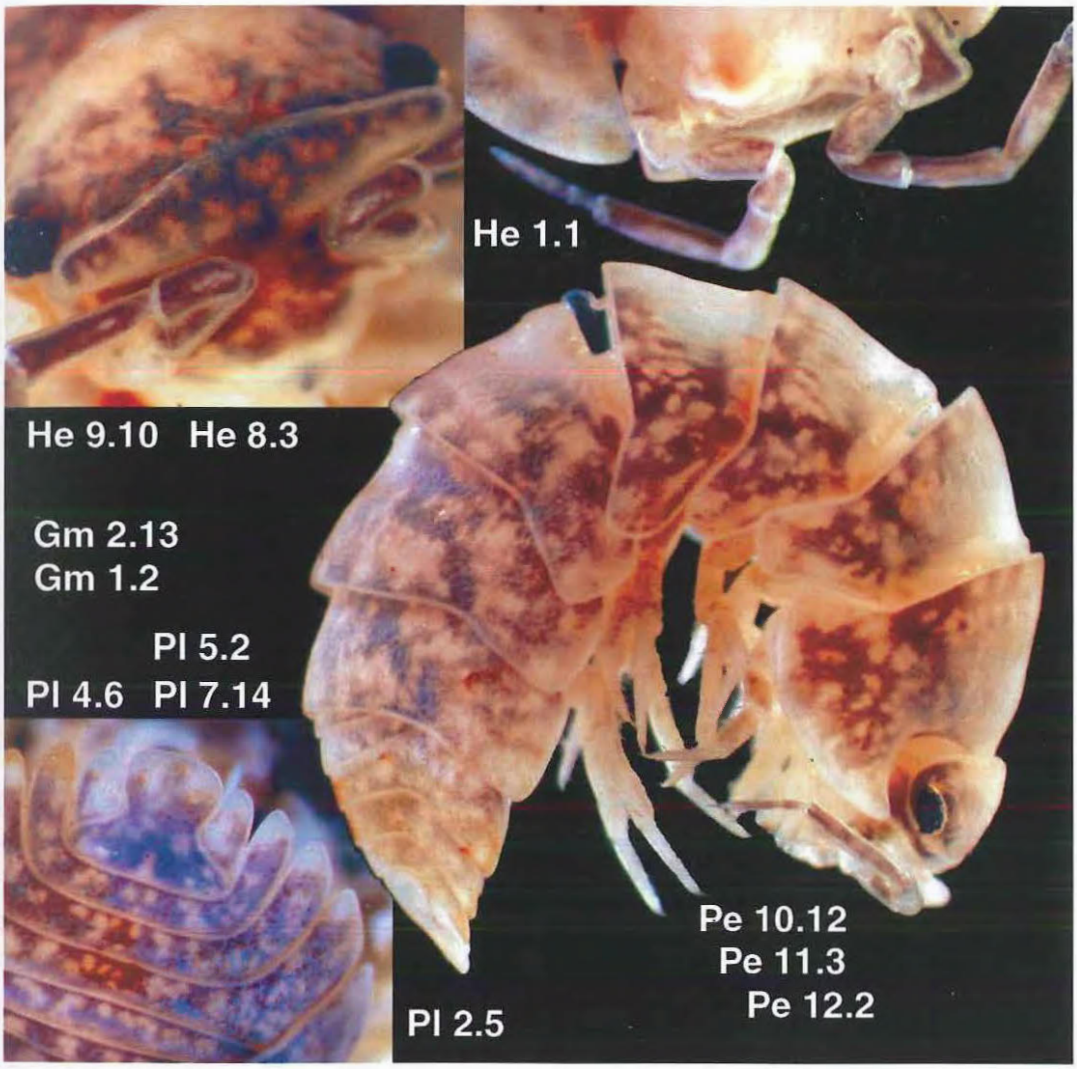


Plate 3.106. Buddelundia **sp. 6 from Warren National Park (C 30912) (length 8 mm).**

3.17.6.10. Buddelundia species 7

Plate 3.2, Gm 2.14; Plate 3 23, Pe 7.2; Plate 3.29, Pe 13.6; Plate 3.40, Pl 7.15; Plate 3.107.

Buddelundia sp. 3 Judd & Horwitz, 2003

MATERIAL EXAMINED. C30896, YANCHEP NATIONAL P[illegible] K -31 5200°S 115 6630°E, JUDD, S , 13-10-98, G40, C30897, HILL RIVER NATIONAL PARK, -30 [illegible]30°S [illegible]1830°E, JUDD, S , 14-10-98, B30, C30898, BULLER NATURE RESERVE, -32.8770°S 115 8300°E, J[illegible] S 12-11-98, L40, C31723, TRIGG NEAR WEST COAST HWAY, -31 8667°S 115 7530°E, WALDO[illegible] [illegible]12-93, P3; C31724, TRIGG E SIDE OF OLD WEST COAST HWAY, -31 8833°S 115 7530°E, WALL[illegible] [illegible]9-08-93, L10, C31725, WEXCOMBE SWAMP TALBOT RD WEXCOMBE SWAMP SITE, -31 8333 S[illegible] [illegible] HARVEY, M. S & WALDOCK, J M., 24-06-93, P3; C31726, TALBOT ROAD RESERVE, -31 8667°S [illegible]3°E, WALDOCK, J M , SAMPEY, A & THORPE, A , 24-09-93, L10; C31727, WEXCOMBE SWAMP WEST SIDE OF TALBOT ROAD OUTSIDE NE CORNER OF RESERVE, -31 8333°S 116 0500°E, WALDOCK, J M & HARVEY, M. S , 24-06-93, P3; C31728, JOONDALUP EDITH COWAN UNIVERSITY CAMPUS, -31 7550°S 115 7833°E, JUDD, S , ??-03-99, P3, C32081, WOODMAN POINT, -32 1306°S 115 7578°E, HARVEY, M S & WALDOCK, J M , 04-05-95, P3, C32096, LANDSDALE SCHOOL, -31.8206°S 115 8503°E, HARVEY, M. S & WALDOCK, J. M , 29-01-96, P3; C32097, LANDSDALE SCHOOL, -31.8206°S 115 8503°E, HARVEY, M. S & WALDOCK, J. M , 25-09-95, P3, C32098, WOODMAN POINT, -32.1328°S 115 7581°E, HARVEY, M. S & WALDOCK, J. M , 06-07-95, P3, C32099, WOODMAN POINT, -32 1328°S 115 7581°E, HARVEY, M. S & WALDOCK, J. M , 05-04-95, P3, C32100, WOODMAN POINT, -32 1306°S 115.7578°E, HARVEY, M. S & WALDOCK, J. M , 06-11-95, P3; C32101, WOODMAN POINT, -32 1328°S 115.7581°E, WALDOCK, J. M. & LONGBOTTOM, A. F , 04-11-94, P3, C32102, WOODMAN POINT, -32 1328°S 115 7581°E, HARVEY, M. S & WALDOCK, J M , 19-01-95, P3, C32103, WOODMAN POINT, -32.1306°S 115 7578°E, WALDOCK, J M & LONGBOTTOM, A. F , 01-09-94, P3; C32104, WOODMAN POINT, -32 1306°S 115 7578°E, HARVEY, M. S & WALDOCK, J M , 19-01-95, P3, C32105, WOODMAN POINT, -32 1297°S 115 7564°E, HARVEY, M. S & WALDOCK, J. M , 06-07-95, P3; C32106, WOODMAN POINT, -32.1328°S 115 7581°E, HARVEY, M. S. & WALDOCK, J. M , 21-03-95, P3; C32107, WOODMAN POINT, -32 1297°S 115 7564°E, HARVEY, M. S & WALDOCK, J. M , 21-03-95, P3, C32108, WOODMAN POINT, -32 1297°S 115 7564°E, WALDOCK, J M & LONGBOTTOM, A F , 01-09-94, P3, C32109, WOODMAN POINT, -32 1328°S 115 7581°E, HARVEY, M. S & WALDOCK, J. M , 06-07-95, P3, C32110, WOODMAN POINT, -32 1297°S 115 7564°E, HARVEY, M. S. & WALDOCK, J. M , 04-05-95, P3, C32111, WOODMAN POINT, -32 1328°S 115 7581°E, WALDOCK, J. M & LONGBOTTOM, A. F., 01-09-94, P3; C32112, WOODMAN POINT, -32.1328°S 115 7581°E, HARVEY, M. S. & WALDOCK, J. M , 04-05-95, P3, C32113, WOODMAN POINT, -32.1306°S 115.7578°E, HARVEY, M. S. & WALDOCK, J. M., 04-05-95, P3, C32114, WOODMAN POINT, -32.1306°S 115 7578°E, HARVEY, M. S. & WALDOCK, J. M , 21-03-95, P3; C32115, WOODMAN POINT, -32 1328°S 115 7581°E, HARVEY, M. S. & WALDOCK, J. M , 21-03-95, P3, C32116, WOODMAN POINT, -32 1328°S 115.7581°E, WALDOCK, J. M & LONGBOTTOM, A. F , 04-11-94, P3; C32117, WOODMAN POINT, -32 1306°S 115 7578°E, WALDOCK, J. M. & LONGBOTTOM, A. F., 04-11-94, P3; C32118, WOODMAN POINT, -32.1328°S 115 7581°E, HARVEY, M. S & WALDOCK, J. M , 19-01-95, P3, C32119, WOODMAN POINT, -32 1297°S 115 7564°E, HARVEY, M. S & WALDOCK, J. M , 19-01-95, P3, C32120, WOODMAN POINT, -32 1297°S 115 7564°E, WALDOCK, J. M & LONGBOTTOM, A. F , 04-11-94, P3, C32121, TUART HILL, -31 8803°S 115 8583°E, WALDOCK, J M ET AL , 23-09-93, P3, C32122, TUART HILL, -31.8803°S 115 8583°E, WALDOCK, J M., 07-01-94, P3; C32123, TUART HILL, -31 8803°S 115 8583°E, HARVEY, M S & WALDOCK, J M., 20-07-93, P3, C32124, TUART HILL, -31 8803°S 115 8583°E, WALDOCK, J M ET AL , 18-11-93, P3, C32125, TUART HILL, -31 8803°S 115 8583°E, HARVEY, M. S & WALDOCK, J. M., 19-05-94, P3, C32126, TUART HILL, -31 8803°S 115 8583°E, HARVEY, M S & WALDOCK, J. M., 21-03-94, P3, C32127, MARANGAROO RESERVE, -31 8308°S 115 8342°E, HARVEY, M S & WALDOCK, J. M , 29-01-96, P3, C32128, MARANGAROO RESERVE, -31 8272°S 115 8344°E, WALDOCK, J M , WEST, P L & WHEELER, A., 28-03-96, P3; C32129, MARANGAROO RESERVE, -31.8308°S 115.8342°E, WALDOCK, J M , WEST, P. L. & WHEELER, A., 28-03-96, P3, C32130, MARANGAROO RESERVE, -31 8272°S 115 8344°E, HARVEY, M. S & WALDOCK, J. M , 28-11-95, P3, C32131, MARANGAROO RESERVE, -31 8272°S 115 8344°E, HARVEY, M. S. & WALDOCK, J. M , 29-01-96, P3, C32132, MARANGAROO RESERVE, -31 8308°S 115 8342°E, HARVEY, M. S & WALDOCK, J. M , 28-11-95, P3; C32133, MT HENRY, -32 0314°S 115 8622°E, HARVEY, M S & WALDOCK, J M , 06-07-95, P3, C32134, MT HENRY, -32 0328°S 115 8606°E, HARVEY, M S & WALDOCK, J. M , 06-07-95, P3; C32135, MT HENRY, -32 0314°S 115 8622°E, HARVEY, M S & WALDOCK, J M , 21-03-95, P3. C32136, MT HENRY, -32.0328°S 115.8606°E, HARVEY, M S & WALDOCK, J M , 21-03-95, P3, C32137, MT HENRY, -32 0314°S 115.8622°E, HARVEY, M. S. & WALDOCK, J M., 04-05-95, P3, C32138, MT HENRY, -32 0314°S 115 8622°E, WALDOCK, J M. & LONGBOTTOM, A F , 04-11-94, P3, C32139, MT HENRY, -32 0314°S 115 8822°E, HARVEY, M. S. & WALDOCK, J M , 14-01-95, P3, C32140, MT HENRY, -32 0328°S 115 8606°E, HARVEY, M S & WALDOCK, J M , 04-05-95, P3, C32141, TRIGG DUNE BUSH, -31 8692°S 115 7606°E, HARVEY, M S & WALDOCK, J M , 25-09-95, P3, C32142, TRIGG DUNE BUSH, -31 8750°S 115 7597°E, HARVEY, M S & WALDOCK, J M , 29-01-96, P3, C32143, TRIGG DUNE BUSH, -31 8750°S 115 7597°E, HARVEY, M S & WALDOCK, J M , 28-11-95, P3, C32144, TRIGG DUNE BUSH, -31 8692°S 115.7606°E, HARVEY, M S & WALDOCK, J M , 29-01-96, P3, C32145, TRIGG DUNE BUSH, -31 8750°S 115 7597°E, HARVEY, M S & WALDOCK, J M , 25-09-95, P3, C32146, BOLD PARK, -31 9417°S 115 7742°E, WALDOCK, J M., 24-09-93, P3, C32147, BOLD PARK, -31 9539°S 115 7711°E, HARVEY, M S. & WALDOCK, J M , 18-03-94, P3, C32148, BOLD PARK, -31.9414°S 115 7869°E, WALDOCK, J M ET AL , 18-11-93, P3, C32149, BOLD PARK, -31 9372°S 115 7711°E, HARVEY, M S & WALDOCK, J. M., 20-07-93, P3; C32150, BOLD PARK, -31 9414°S 115 7669°E, HARVEY, M S. & WALDOCK, J M., 18-03-94, P3; C32151, BOLD PARK, -31 9417°S 115 7742°E, HOW, R , 24-12-93, P2, C32152, BOLD PARK, -31 9364°S 115 7639°E, WALDOCK, J. M ET AL , 24-09-93, P3, C32153, BOLD PARK, -31 9417°S 115 7742°E,

HARVEY, M. S. & WALDOCK, J. M., 18-03-94, P3, C32154, BOLD PARK, -31 9417°S 115 7639°E, HARVEY, M. S. & WALDOCK, J. M., 20-07-93, P3; C32155, BOLD PARK, -31 9417°S 115 7742°E, HARVEY, M. S. & WALDOCK, J. M., 19-05-94, P3; C32156, BOLD PARK, -31 9364°S 115 7639°E, HARVEY, M. S. & WALDOCK, J. M., 18-03-94, P3; C32157, BOLD PARK, -31 9372°S 115 7711°E, WALDOCK, J. M., 24-09-93, P3; C32158, BOLD PARK, -31 9372°S 115 7711°E, HARVEY, M. S. & WALDOCK, J. M., 19-05-94, P3; C32159, BOLD PARK, -31 9425°S 115.7703°E, HARVEY, M. S. & WALDOCK, J. M., 20-07-93, P3, C32160, BOLD PARK, -31 9417°S 115 7742°E, WALDOCK, J. M., 06-01-94, P3, C32161, BOLD PARK, -31 9372°S 115 7711°E, WALDOCK, J. M. ET AL., 19-11-93, P3, C32162, BOLD PARK, -31 9364°S 115 7639°E, WALDOCK, J. M. ET AL., 18-11-93, P3; C32163, BOLD PARK, -31.9414°S 115 7669°E, WALDOCK, J. M., GOODSELL, J. & WEBB, J., 06-01-94, P3; C32164, BOLD PARK, -31 9372°S 115 7711°E, WALDOCK, J. M., 06-01-94, P3, C32165, BOLD PARK, -31 9414°S 115 7669°E, HARVEY, M. S. & WALDOCK, J. M., 19-05-94, P3, C32166, TRIGG DUNE BUSH, -31 8750°S 115 7597°E, WALDOCK, J. M. & WEST, P. L., 28-03-96, P3; C32167, JANDAKOT AIRPORT, -32 0919°S 115.8744°E, WALDOCK, J. M. & HARVEY, M. S., 19-01-95, P3, C32168, JANDAKOT AIRPORT, -32 0919°S 115 8744°E, WALDOCK, J. M. & LONGBOTTOM, A. F., 01-09-94, P3; C32169, JANDAKOT AIRPORT, -32 0919°S 115 8744°E, WALDOCK, J. M. & LONGBOTTOM, A. F., 04-11-94, P3, C32170, JANDAKOT AIRPORT, -32 0919°S 115 8744°E, WALDOCK, J. M. & HARVEY, M. S., 06-07-95, P3, C32171, JANDAKOT AIRPORT, -32 0919°S 115 8744°E, WALDOCK, J. M. & HARVEY, M. S., 04-05-95, P3, C32172, JANDAKOT AIRPORT, -32 0919°S 115.8744°E, WALDOCK, J. M. & HARVEY, M. S., 21-03-95, P3; C32173, JANDAKOT AIRPORT, -32 0933°S 115 8775°E, WALDOCK, J. M. & HARVEY, M. S., 19-01-95, P3, C32174, JANDAKOT AIRPORT, -32 0933°S 115 8775°E, WALDOCK, J. M. & HARVEY, M. S., 21-03-95, P3, C32175, JANDAKOT AIRPORT, -32 0933°S 115 8775°E, WALDOCK, J. M. & HARVEY, M. S., 06-07-95, P3; C32176, JANDAKOT AIRPORT, -32 0933°S 115 8775°E, WALDOCK, J. M. & HARVEY, M. S., 04-05-95, P3, C32177, JANDAKOT AIRPORT, -32 0933°S 115 8775°E, WALDOCK, J. M. & LONGBOTTOM, A. F., 04-11-94, P3; C32178, JANDAKOT AIRPORT, -32 0933°S 115.8775°E, WALDOCK, J. M. & LONGBOTTOM, A. F., 01-09-94, P3; C32179, HEPBURN HEIGHTS, -31 8172°S 115 7703°E, WALDOCK, J. M. & HARVEY, M. S., 29-01-96, P3, C32180, HEPBURN HEIGHTS, -31 8172°S 115.7703°E, WALDOCK, J. M., WEST, P. L. & WHEELER, A., 28-03-96, P3, C32181, HEPBURN HEIGHTS, -31.8158°S 115 7781°E, WALDOCK, J. M. & HARVEY, M. S., 25-09-95, P3, C32182, HEPBURN HEIGHTS, -31.8183°S 115 7672°E, WALDOCK, J. M. & HARVEY, M. S., 29-01-96, P3, C32183, PERTH AIRPORT, -31.9767°S 115 9744°E, WALDOCK, J. M. & HARVEY, M. S., 18-03-94, P3; C32184, PERTH AIRPORT, -31.9767°S 115 9744°E, WALDOCK, J. M., GOODSELL, J. & WEBB, J., 06-01-94, P3, C32185, PERTH AIRPORT, -31 9675°S 115 9697°E, WALDOCK, J. M. ET AL., 18-11-93, P3; C32186, MT CLAREMONT, -31 9611°S 115.7667°E, WALDOCK, J. M. & HARVEY, M. S., 04-05-95, P3, C32187, MT CLAREMONT, -31 9611°S 115 7667°E, WALDOCK, J. M. & LONGBOTTOM, A. F., 01-09-94, P3, C32188, MT CLAREMONT, -31 9611°S 115 7667°E, WALDOCK, J. M. & HARVEY, M. S., 06-07-95, P3; C32189, MT CLAREMONT, -31 9611°S 115.7667°E, WALDOCK, J. M. & HARVEY, M. S., 19-01-95, P3; C32190, MT CLAREMONT, -31 9611°S 115.7667°E, WALDOCK, J. M. & LONGBOTTOM, A. F., 04-11-94, P3, C32191, MT CLAREMONT, -31.9608°S 115 7656°E, WALDOCK, J. M. & LONGBOTTOM, A. F., 04-11-94, P3; C32192, MT CLAREMONT, -31 9608°S 115 7656°E, WALDOCK, J. M. & LONGBOTTOM, A. F., 06-07-95, P3; C32193, MT CLAREMONT, -31 9608°S 115.7656°E, WALDOCK, J. M. & HARVEY, M. S., 21-03-95, P3, C32194, MT CLAREMONT, -31 9608°S 115 7656°E, WALDOCK, J. M. & HARVEY, M. S., 19-01-95, P3; C32195, MT CLAREMONT, -31.9608°S 115 7656°E, WALDOCK, J. M. & LONGBOTTOM, A. F., 01-09-94, P3; C32196, TALBOT ROAD RESERVE, -31 8681°S 116.0511°E, DELL, J., 24-03-94, P2; C32197, TALBOT ROAD RESERVE, -31.8681°S 116 0511°E, WALDOCK, J. M. & HARVEY, M. S., 24-06-93, P3, C32198, TALBOT ROAD RESERVE, -31 8681°S 116.0511°E, WALDOCK, J. M. ET AL., 18-11-93, P3, C32199, TALBOT ROAD RESERVE, -31 8681°S 116 0511°E, WALDOCK, J. M. & HARVEY, M. S., 18-03-94, P3, C32200, TALBOT ROAD RESERVE, -31 8681°S 116.0511°E, WALDOCK, J. M., GOODSELL, J. & WEBB, J., 06-01-94, P3, C32201, TALBOT ROAD RESERVE, -31 8681°S 116 0511°E, WALDOCK, J. M. & HARVEY, M. S., 28-07-93, P3, C32202, TALBOT ROAD RESERVE, -31.8681°S 116 0511°E, WALDOCK, J. M. & HARVEY, M. S., 19-05-94, P3, C32203, TALBOT ROAD RESERVE, -31 8731°S 116 0461°E, WALDOCK, J. M. ET AL., 18-11-93, P3, C32204, TALBOT ROAD RESERVE, -31 8731°S 116.0461°E, DELL, J., 31-10-93, P2; C32205, TALBOT ROAD RESERVE, -31 8733°S 116 0478°E, DELL, J., 29-08-93, P2, C32206, TALBOT ROAD RESERVE, -31 8733°S 116 0478°E, WALDOCK, J. M., 10-12-93, P3, C32207, TALBOT ROAD RESERVE, -31 8733°S 116 0478°E, WALDOCK, J. M., 10-12-93, P3, C32208, TALBOT ROAD RESERVE, -31 8733°S 118 0478°E, DELL, J., 29-08-93, P2, C32209, TALBOT ROAD RESERVE, -31 8731°S 116.0461°E, WALDOCK, J. M. & HARVEY, M. S., 28-07-93, P3, C32210, TALBOT ROAD RESERVE, -31 8731°S 116 0461°E, DELL, J., 29-08-93, P2; C32211, TALBOT ROAD RESERVE, -31.8731°S 116.0461°E, WALDOCK, J. M., 10-12-93, P3, C32212, TALBOT ROAD RESERVE, -31 8733°S 116 0478°E, WALDOCK, J. M. ET AL., 18-11-93, P3, C32213, TALBOT ROAD RESERVE, -31.8733°S 116 0478°E, WALDOCK, J. M. ET AL., 23-09-93, P3, C32214, TRIGG DUNE BUSH, -31 8692°S 115 7606°E, WALDOCK, J. M. & HARVEY, M. S., 28-11-95, P3; C32215, BOLD PARK, -31 9414°S 115.7669°E, WALDOCK, J. M., 24-09-93, P3.

Diagnosis: Habitus roller. Animal light cream in colour with darker brown patches with well-defined broad cream coloured band along lateral margins of animal. Frontal ridge formed by a single well-defined line in a smooth arc. Eyes large and clypeal lobes inconspicuous. Pereonite 1 without deep furrow parallel to lateral margin (sulcus arcuatus). Outer and inner lobes of pereonal epimeron 1 sub-equal in length. Posterior margin of pereonal epimeron 1 nearly straight. Dorsal surface of pereonites smooth. Pereonal epimeron 2 pointed. Telson very short with little difference in width between mid-point and distal margin.

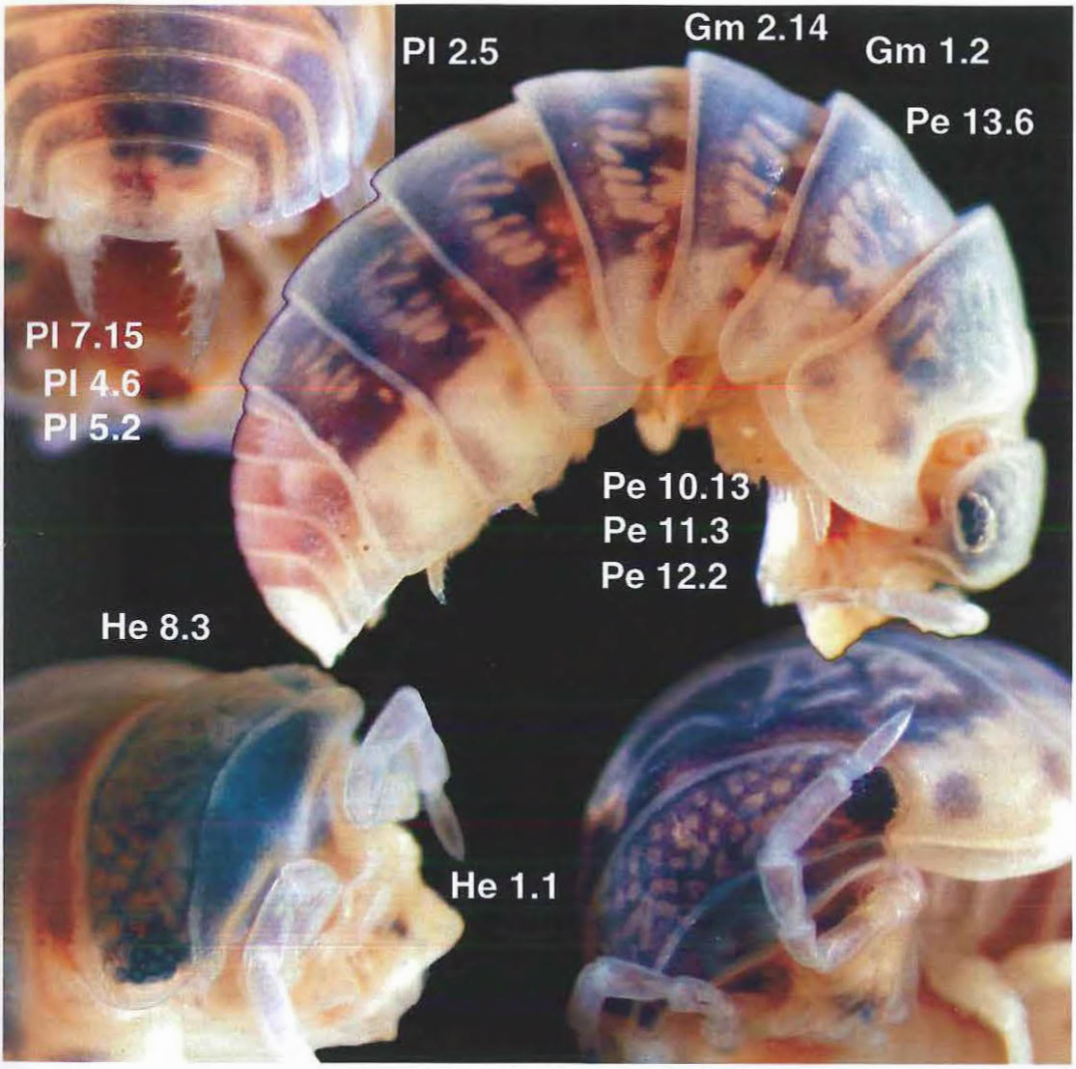


Plate 3.107. Buddelundia species 7 from Talbot Road Reserve (C 32199) (length 6 mm).

3.17.6.11. Buddelundia nigripes Budde-Lund, 1912

Plate 3.2, Gm 2.15; Plate 3.9, He 5.7; Plate 3.26, Pe 10.13; Plate 3.28, Pe 12.17; Plate 3.32, Pe 16.1; Plate 3.38, Pl 5.26b; Plate 3.108.

Armadillo (Buddelundia) nigripes Budde-Lund, 1912

Buddelundia nigripes Vandel, 1973

TYPE MATERIAL EXAMINED: C396, SYNTYPE, BUNBURY, HAMBURG EXPEDITION STN 142, WA, 24/25-07-05

MATERIAL EXAMINED: C1489/90, CLAREMONT, -31 9833*S 115.7833*E, GLAUERT, L., ??-??-24; C1619, FRESHWATER BAY, SWAN RIVER, -32 0000*S 115 7833*E, GLAUERT, L., ??-??-25; C1621, FRESHWATER BAY, SWAN RIVER, -32 0000*S 115.7833*E, GLAUERT, L., ??-??-25; C1622, FRESHWATER BAY, SWAN RIVER, -32 0000*S 115 7833*E, GLAUERT, L., ??-??-25, C2352/65, PEPPERMINT GROVE PERTH, -32 0000*S 115.7667*E, GLAUERT, L., ??-??-27; C2402/11, SWAN RIVER MINIM COVE, -32.0167*S 115.7667*E, GLAUERT, L., ??-??-27; C5804/12, CALGARDUP BEACH AT BOBISHALLOW, -34.0333*S 115.0000*E, GLAUERT, L., ??-??-40, G30; C21087, MEELUP 6.5 KM NW, -33 5583*S 115 0167*E, HAROLD, G. A., 27-10-85; C29701, MARGARET RIVER DISTRICT, -33 9500*S 115 0667*E, , ??-??-??; C30786, WELLINGTON MILL, -33 4430*S 115.9080*E, JUDD, S., 30-07-98, L10; C30787, WELLINGTON MILL, -33 4430*S 115.9080*E, JUDD, S., 30-07-98, S1; C30788, WELLINGTON MILL, -33.4430*S 115 9080*E, JUDD, S., 30-07-98, G20, C30789, MT LENNARD, -33.3920*S 115.8870*E, JUDD, S., 30-07-98, B50, C30790, MT. LENNARD COLLIE RIVER, -33 3620*S 115 9030*E, JUDD, S., 30-07-98, G20; C30791, YANCHEP NATIONAL PARK, -31.5200*S 115.6630*E, JUDD, S., 13-10-98, L20; C30792/4, YANCHEP NATIONAL PAPK, -31.5200*S 115.6630*E, JUDD, S., 13-10-98, L10, C30795, YANCHEP NATIONAL PARK, -31.5200*S 115 6630*E, JUDD, S., 13-10-98, G40, C30796/7, YANCHEP NATIONAL PARK, -31.5200*S 115 6630*E, JUDD, S., 13-10-98, R4; C30798, YALGORUP NATIONAL PARK, -32.9130*S 115.6830*E, JUDD, S., 13-11-98, B30; C30799, YALGORUP NATIONAL PARK, -32 9130*S 115 6830*E, JUDD, S., 13-11-98, L10; C30800, YALGORUP NATIONAL PARK, -32 9130*S 115 6830*E, JUDD, S., 13-11-98, L40, C30801, LESCHENAULT CONSERVATION PARK, -33 2250*S 115.6920*E, JUDD, S., 25-11-98, L70; C30802, LESCHENAULT CONSERVATION PARK, -33 2250*S 115.6920*E, JUDD, S., 25-11-98, L10, C30803, CHALK BROOK (LANE POOLE RESERVE), -33.0670*S 116.2320*E, JUDD, S., 26-11-98, B50; C30804, CHALK BROOK (LANE POOLE RESERVE), -33.0670*S 116 2320*E, JUDD, S., 26-11-98, L10; C30805, CHALK BROOK (LANE POOLE RESERVE), -33 0670*S 116 2320*E, JUDD, S., 26-11-98, L20; C30806, CHALK BROOK (LANE POOLE RESERVE), -33 0670*S 116 2320*E, JUDD, S., 26-11-98, R3; C30807, LEEUWIN NATURALISTE NATIONAL PARK (QUININUP KARRI), -33.7350*S 115 0070*E, JUDD, S., 07-12-98, L10, C30808, LEEUWIN NATURALISTE NATIONAL PARK (QUININUP KARRI), -33 7350*S 115.0070*E, JUDD, S., 07-12-98, B10; C30809/10, LEEUWIN NATURALISTE NATIONAL PARK HAMELIN BAY, -34 2070*S 115.0380*E, JUDD, S., 10-12-98, S1; C30811, LEEUWIN NATURALISTE NATIONAL PARK KARRI NEAR HAMELIN BAY, -34 2000*S 115.0720*E, JUDD, S., 10-12-98, L10; C30812, LEEUWIN NATURALISTE NATIONAL PARK KARRI NEAR HAMELIN BAY, -34.2000*S 115.0720*E, JUDD, S., 10-12-98, R4; C31639, CAPE CLAIRAULT, -33.7025*S 114 9812*E, JUDD, S., 15-07-98, R4; C31640, GNOOCARDUP SEEP LEEUWIN NATURALISTE NATIONAL PARK W EDGE, -33.9333*S 115 0000*E, SLACK-SMITH, S., 26-11-85, L90; C31641, GNOOCARDUP SEEP LEEUWIN NATURALISTE NATIONAL PARK, -33.9333*S 115.0000*E, SLACK-SMITH, S., 26-11-85, L60, C31642, GNOOCARDUP, -33 9333*S 115.0000*E, SLACK-SMITH, S., 04-08-85, L50; C31643, GNOOCARDUP SEEP LEEUWIN NATURALISTE NATIONAL PARK, -33.9333*S 115 0000*E, SLACK-SMITH, S., 26-11-85, L50; C31644, GNOOCARDUP, -33.9333*S 115 0000*E, SLACK-SMITH, S., 04-08-85, L50, C31645, DEEPDENE HALF MILE NORTH, -34 2667*S 115 0833*E, PATERSON, A., 10-07-71, L41; C31646, FLINDERS BAY, AUGUSTA, -34.3167*S 115 1800*E, NICHOLLS COLLECTION, ??-08-32, C31647, D'ENTRECASTEAUX NATIONAL PARK, POINT D'ENTRECASTEAUX, -34.8333*S 116 0000*E, HARVEY, M. S. & WALDOCK, J. M., 25-03-93, R4, C31648, GNOOCARDUP, -33.9333*S 115.0000*E, SLACK-SMITH, S., 04-08-85; C31649, D'ENTRECASTEAUX NATIONAL PARK, POINT D'ENTRECASTEAUX, -34 8333*S 116 0000*E, HARVEY, M. S. & WALDOCK, J. M., 01-05-90, R4, C31650, YANCHEP NATIONAL PARK BOOMERANG GORGE, -31 5167*S 115 7667*E, WALDOCK, J. M. & SAMPEY, A., 20-04-93; C31651, BORANUP, -34.1500*S 115 0333*E, RILEY, G. M., 11-09-65; C31652/56, CAPE LEEUWIN FRESHWATER SWAMP, -34.3667*S 115.1333*E, SLACK-SMITH, S., 09-11-97; C31657/8, GLENBOURNE FARM OLD ELLENSBROOK ROAD NEAR MARGARET RIVER, -33 9167*S 115.0167*E, MARSH, L. ET AL., 28-10-96, P2; C31659/62, GLENBOURNE FARM OLD ELLENSBROOK ROAD NEAR MARGARET RIVER, -33.9167*S 115 0167*E, MARSH, L. ET AL., 31-03-97, P2, C31663/67, GLENBOURNE FARM OLD ELLENSBROOK ROAD NEAR MARGARET RIVER, -33 9167*S 115.0167*E, MARSH, L. ET AL., 30-06-97, P2; C31668/69, GLENBOURNE FARM OLD ELLENSBROOK ROAD NEAR MARGARET RIVER, -33 9167*S 115 0167*E, MARSH, L. ET AL., 15-09-97, P2; C31670/73, GLENBOURNE FARM OLD ELLENSBROOK ROAD NEAR MARGARET RIVER, -33 9167*S 115.0167*E, MARSH, L. ET AL., 29-12-97, P2; C31674, GLENBOURNE FARM OLD ELLENSBROOK ROAD NEAR MARGARET RIVER, -33 9167*S 115.0167*E, MARSH, L. ET AL., 20-05-98, P2; C31675, GLENBOURNE FARM OLD ELLENSBROOK ROAD NEAR MARGARET RIVER, -33 9167*S 115 0167*E, MARSH, L. ET AL., 20-05-98, P2; C31676, CAPE LEEUWIN SWAMP WEST EDGE OF SWAMP, -34 3667*S 115 1333*E, SLACK-SMITH, S. ET AL., 19-08-00, S1; C31677, CAPE LEEUWIN SWAMP WEST EDGE OF SWAMP NEAR PIEZOMETER, -34.3667*S 115 1333*E, SLACK-SMITH, S. ET AL., 19-08-00, S1; C31678, CAPE LEEUWIN SWAMP WEST EDGE OF SWAMP AT BASE OF RISE, -34 3667*S 115 1333*E, SLACK-SMITH, S. ET AL., 19-08-00, S1; C31679, CAPE LEEUWIN SWAMP SOUTH SIDE OF SWAMP NEAR AND AT BASE OF SLOPE, -34.3667*S 115 1333*E, SLACK-SMITH, S. ET AL., 19-08-00, L10; C31680, CAPE LEEUWIN SWAMP NORTHWEST OF SWAMP ON SLIGHT RISE, -34.3667*S 115 1333*E, SLACK-SMITH, S. ET AL., 20-08-00, L10; C31681,

CAPE LEEUWIN SWAMP NORTHWEST OF SWAMP ON SLIGHT RISE, -34 3667°S 115 1333°E, SLACK-SMITH, S ET AL., 20-08-00, S1, C31682, CAPE LEEUWIN SWAMP WESTERN EDGE OF SWAMP ADJACENT TO ROCK OUTCROP, -34 3667°S 115 1333°E, SLACK-SMITH, S. ET AL., 20-08-00, L10; C31683/4, GLENBOURNE FARM OLD ELLENSBROOK ROAD NEAR MARGARET RIVER, -33 9167°S 115 0167°E, MARSH, L ET AL., 26-10-98, P2, C31685, YALLINGUP BROOK SOUTH SIDE OF LOWER REACHES, COUNCIL RESERVE, -33 6439°S 115 0289°E, APLIN, K , 08-04-00, P1

Diagnosis: Habitus roller. Animal with very distinctive cream and brownish purple in colour with blotchy appearance. Without cream coloured band along lateral margin. Frontal ridge formed by single well-defined line in smooth arc. Head with raised bumps behind frontal ridge but separated from frontal ridge. Clypeal lobes with little frontal projection and sub-square in shape. Pereonite 1 without deep furrow parallel to lateral margin (sulcus arcuatus). Posterior margin of pereonal epimeron 1 angled slightly backward or nearly straight. Dorsal surface of pereonites smooth except for some shallow bumps on first pereonite. Posterior lateral corner of pereonal epimeron 1 produced with a kink at junction with thickened lateral margin of epimeron 1. Inner lobe of pereonal epimeron 1 and posterior lateral epimeron border of pereonal epimeron 1 sub-equal in length. Pereonal epimeron 2 rounded. Pereopods are of two colours and match the appearance of animal. Telson wide and quite long, slightly wider at distal margin than at midpoint with slightly rounded appearance.

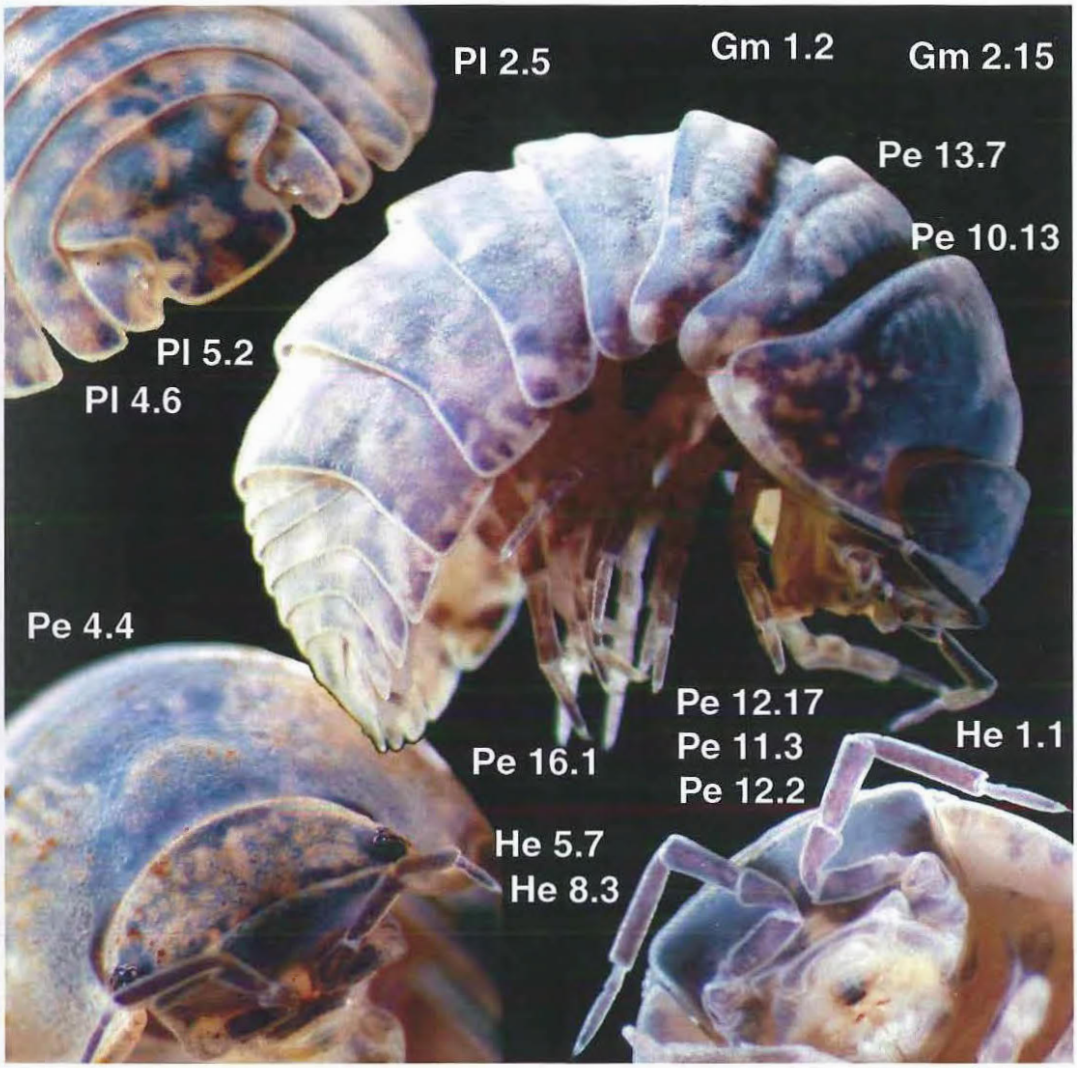


Plate 3.108. Buddelundia nigripes **from Leschenault Conservation Park (close to the type locality) (C 30802) (length 8 mm).**

3.17.6.12. Buddelundia nitidissima Budde-Lund, 1912

Plate 3.26, Pe 10.14; Plate 3.28, Pe 12.2; Plate 3.29, Pe 13.7; Plate 3.32, Pe 16.2; Plate 3.109.

Armadillo (Buddelundia) nitidissimus Budde-Lund, 1912

Buddelundia nitidissima Vandel, 1973

Buddelundia nitidissima Judd & Horwitz, 2003

MATERIAL EXAMINED C372, HARVEY FLATLAND WEST OF DARLING RANGE, -33.0833°S 115 9000°E, HAMBURG EXPEDITION, 27-08-05; C1667, DANDARAGAN, -30 6667°S 115 7000°E, GLAUERT, L., ??-??-25; C5194, MANJIMUP, PERUP?, -34 3333°S 116 4500°E, GLAUERT, L., ??-03-36, G30; C18412, WOOROLOO, -31 8000°S, 116 3167°E, COLLECTOR UNKNOWN, 17-04-33; C30841, RIDLEY ROAD MT YETAR, -31.9420°S 116.4000°E, JUDD, S., 22-07-98, R2; C30842, RIDLEY ROAD MT. YETAR, -31.9420°S 116.4000°E, JUDD, S., 22-07-98, L10; C30843, LEONA ROAD, -32 2180°S 116 3250°E, JUDD, S., 23-07-98, G30; C30844/6, DRYANDRA (LIONS VILLAGE), -32 7870°S 116 9820°E, JUDD, S., 07-09-98, L10; C30847, DRYANDRA (LIONS VILLAGE), -32.7870°S 116.9820°E, JUDD, S., 07-09-98, L42; C30848, BINDOON SPRING, -31.4080°S 116 3670°E, JUDD, S., 09-10-98, G40; C30849, MOGANMOGANNING NATURE RESERVE, -31.1200°S 116 2530°E, JUDD, S., 11-10-98, L10; C30850, MOGANMOGANNING NATURE RESERVE, -31 1200°S 116.2530°E, JUDD, S., 11-10-98, G20; C30851, MOGANMOGANNING NATURE RESERVE, -31.1200°S 116 2530°E, JUDD, S., 11-10-98, G30; C30852, MOUNT BYROOMANNING NR, -31.3730°S 116.1270°E, JUDD, S., 18-10-98, L10, C30853, CLACKLINE NATURE RESERVE, -31.7000°S 116.4830°E, JUDD, S., 20-10-98, L30; C30854, CLACKLINE NATURE RESERVE, -31.7000°S 116.4830°E, JUDD, S , 20-10-98, G30; C30855, WAMBYN NATURE RESERVE, -31.8980°S 116.6350°E, JUDD, S., 21-10-98, L30, C30856, ST. RONANS NATURE RESERVE, -31.8730°S 116.6400°E, JUDD, S., 21-10-98, L10, C30857, WANDOO CONSERVATION PARK, -32.0520°S 118.5450°E, JUDD, S., 22-10-98, L10, C30858, WANDOO CONSERVATION PARK, -32 0520°S 116.5450°E, JUDD, S., 22-10-98, R2; C30859, WANDOO CONSERVATION PARK, -32.0520°S 116 5450°E, JUDD, S., 22-10-98, G30; C30860, WANDOO CONSERVATION PARK, -32.0520°S 116.5450°E, JUDD, S , 22-10-98, L10, C30861, DABBABERRY NATURE RESERVE, -32.2070°S 116.5700°E, JUDD, S., 22-10-98, G30; C30862, LUPTON CONSERVATION PARK NORTH, -32 4470°S 116.8430°E, JUDD, S , 26-10-98, L10, C30863, LUPTON CONSERVATION PARK NORTH, -32.4470°S 116.6430°E, JUDD, S., 28-10-98, G30; C30864, STRANGE ROAD NATURE RESERVE, -32 4030°S 116 6150°E, JUDD, S., 26-10-98, L20; C30865, FLINT BLOCK BOYAGARRING/COLIN ROAD, -32 2970°S 116.5430°E, JUDD, S., 28-10-98, G30; C30866, LUPTON CONSERVATION PARK SOUTH, -32 5570°S 116.6930°E, JUDD, S , 28-10-98, G30, C30867, MOORAPULLING NATURE RESERVE, -32 9020°S 116 5730°E, JUDD, S., 28-10-98, L10; C30868, MOORAPULLING NATURE RESERVE, -32 9020°S 116.5730°E, JUDD, S , 28-10-98, L20; C30869, JINGALUP NATURE RESERVE, -34.0130°S 117.0130°E, JUDD, S., 29-10-98, L10; C30870, JINGALUP NATURE RESERVE, -34 0130°S, 117 0130°E, JUDD, S , 29-10-98, G30; C30871, PROPOSED LANE POOLE EXTENSION, -33.2030°S 116 4630°E, JUDD, S., 30-10-98, G30; C30872, SCHULSTAAD ROAD CREEK, -32.2800°S 116 3600°E, JUDD, S., 05-11-98, G30; C30873, SCHULSTAAD ROAD CREEK, -32.2800°S 116.3600°E, JUDD, S , 05-11-98, L10, C30874, KEN ROAD STATE FOREST, -32.5320°S 116 2850°E, JUDD, S., 06-11-98, G30; C30875, KEN ROAD STATE FOREST, -32.5320°S 116.2850°E, JUDD, S., 06-11-98, L10; C30876, PRESTON CONSERVATION PARK, -33 6030°S 116 0630°E, JUDD, S., 24-11-98, L10; C30877, LUDLOW TUART FOREST, -33 6150°S 115.4670°E, JUDD, S., 25-11-98, G30; C30878/9, BURNSIDE ROAD NATURE RESERVE, -32.7230°S 115.9430°E, JUDD, S., 03-12-98, L10; C30880, BURNSIDE ROAD NATURE RESERVE, -32.7230°S 115 9430°E, JUDD, S., 03-12-98, R1; C30881, YELVERTON STATE FOREST, -33.7380°S 115.1020°E, JUDD, S., 07-12-98, G30; C30882, DENBARKER BLOCK (STAN ROAD), -34.8250°S 117.3470°E, JUDD, S , 08-01-99, R3; C30883, DENBARKER BLOCK (STAN ROAD), -34.8250°S 117.3470°E, JUDD, S , 08-01-99, G30; C30884/5, CLEAR HILLS/WATERSHED ROAD, -34.6980°S 117.1820°E, JUDD, S., 01-09-99, G30; C30886, MOUNT DALE, -32.1011°S 116 2875°E, JUDD, S. & WATSON, A., 14-10-01, G10; C30887, MOUNT DALE, -32 0834°S 116.2831°E, JUDD, S. & WATSON, A , 14-12-01, G10; C30888, MOUNT DALE, -32.0885°S 116.2810°E, JUDD, S. & WATSON, A., 21-06-01, G10; C30889, MOUNT DALE, -32.1040°S 116 2766°E, WATSON, A., 01-10-01, P3; C30890, MOUNT DALE, -32.1120°S 116.2875°E, WATSON, A , 01-10-01, P3; C30891, DABBABERRY NATURE RESERVE, -32.2070°S 116.5700°E, JUDD, S., 22-10-98, G30; C31703, TWO PEOPLES BAY NEAR CAMP, -34.9833°S 118.1667°E, ZOOL. CAMP?, 18-01-35, G30, C31704, PEMBERTON, -34.4500°S 116.0333°E, NICHOLLS COLLECTION, ??-03-23; C31705, MT COOKE, BASE OF MOUNT COOKE, -32.4167°S 116.3000°E, HARVEY, M. S , WALDOCK, J. M. & PETERSON, M., 07-08-90; C31706, MT COOKE, -32.4167°S 118.3000°E, HARVEY, M. S & WALDOCK, J. M., 18-04-91; C31707, MT COOKE, -32.4167°S 116.3000°E, HARVEY, M. S & WALDOCK, J M , 19-09-91; C31708, MT COOKE NEAR SUMMIT, -32.4167°S 116.3000°E, HARVEY, M. S , WALDOCK, J. M & PETERSON, M., 07-08-90, C31709/10, MT COOKE, -32.4167°S 116.3000°E, HARVEY, M. S. & WALDOCK, J M., 27-04-92; C31711, NEDLANDS UNIVERSITY OF W A, -31 9833°S 115.8000°E, NICHOLLS COLLECTION, 09-09-28; C31712, ROELANDS, -33 3000°S 115.8333°E, JENKINS, C. F. H., 21-05-34; C31713, STIRLING RANGE NATIONAL PARK WHITE GUM FLAT, -34.4000°S 117 9167°E, WALDOCK, J M. & SAMPEY, A., 11-06-93, L10; C31714, STIRLING RANGE NATIONAL PARK WHITE GUM FLAT, -34 4000°S 117 9167°E, HARVEY, M. S. & WALDOCK, J. M., 01-04-93, B20; C31715, STIRLING RANGE NATIONAL PARK WHITE GUM FLAT, -34.4000°S 117.9167°E, HARVEY, M. S & WALDOCK, J. M., 01-04-93, R1; C31716, MT DALE WITHIN 300M OF SUMMIT, -32.1333°S 116 3000°E, JUDD, S., 29-03-00, L10; C31717, MT DALE WITHIN 300M OF SUMMIT, -32.1333°S 116.3000°E, JUDD, S., 29-03-00, G30; C31718, MT DALE WITHIN 300M OF SUMMIT, -32 1333°S 116.3000°E, JUDD, S., 29-03-00, L10; C31719, MT DALE WITHIN 300M OF SUMMIT, -32 1333°S 116 3000°E, JUDD, S., 29-03-00, L40; C31720, MT DALE WITHIN 300M OF SUMMIT, -32 1333°S

116.3000°E, JUDD, S., 29-03-00, L10; C32092, BRICKWOOD RESERVE, CARDUP, -32.2339°S 116.0019°E, WALDOCK, J. M., WEST, P. L. & LONGBOTTOM, A., 17-06-96, P3; C32093, BRICKWOOD RESERVE, CARDUP, -32.2333°S 116.0006°E, WALDOCK, J. M., WEST, P. L. & LONGBOTTOM, A., 17-06-96, P3; C32094, CARDUP RESERVE, -32.2431°S 115.9856°E, WALDOCK, J. M., WEST, P. L. & LONGBOTTOM, A., 17-06-96, P3; C32095, CARDUP RESERVE, -32.2444°S 115.9875°E, WALDOCK, J. M., WEST, P. L. & LONGBOTTOM, A., 17-06-96, P3.

Diagnosis: Habitus roller. Animal of uniform pale grey/brown colour. Some faint markings become evident microscopically upon preservation. Frontal ridge formed by single well-defined line. Clypeal lobes with little forward projection and sub square in shape. Pereonite 1 without deep furrow parallel to lateral margin (sulcus arcuatus). Dorsal surface of head and pereonites smooth. Posterior margin of pereonal epimeron 1 almost straight. Posterior lateral border of pereonal epimeron 1 produced with kink at junction with thickened lateral margin at junction with inner lobe. Pereonal epimeron 2 rounded. Pereopods of single colour. Telson quite long and wider at distal border than midpoint.

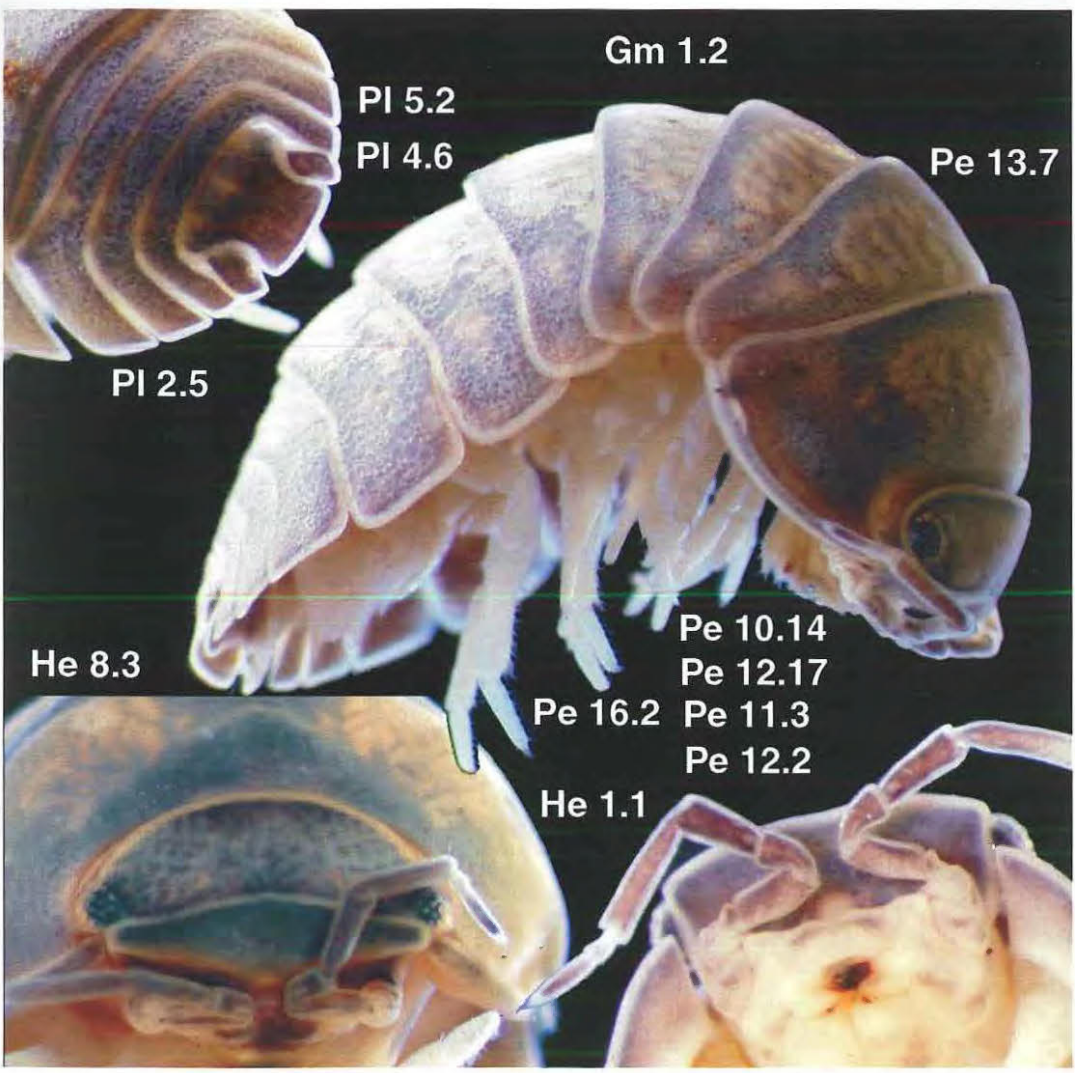


Plate 3.109. Buddelundia nitidissima from St. Ronan's Well Nature Reserve (C30856) (length 9 mm)

3.17.6.13. Buddelundia albomaculata Budde-Lund, 1912

Plate 3.12, He 8.3; Plate 3.21, Pe 5.4; Plate 3.28, Pe 12.18; Plate 3.29, Pe 13.8; Plate 3.110.

Armadillo (Buddelundia) albomaculatus Budde-Lund, 1912

Buddelundia albomaculata Vandel, 1973

TYPE MATERIAL EXAMINED: C394, SYNTYPE, BROOMEHILL, HAMBURG EXPEDITION STN 158, WA, 24-08-05.

MATERIAL EXAMINED: C30892, HILLMAN NATURE RESERVE, -33.3170°S 118.8070°E, JUDD, S., 28-10-98, L10; C30893, HILLMAN NATURE RESERVE, -33.3170°S 116.8070°E, JUDD, S., 28-10-98, B40; C30894, NARLINGUP NATURE RESERVE, -33.8630°S 116.8900°E, JUDD, S., 29-10-98, G30; C31721, STIRLING RANGE NATIONAL PARK CARAVAN PARK, -34.3167°S 118.2000°E, HARVEY, M. S. & WALDOCK, J. M., 02-04-93, L42; C31722, DRYANDRA WOODLAND E. OF WANDERING-NARROGIN RD, -32.7597°S 117.1208°E, HARVEY, M. S., WALDOCK, J. M. & DESMOND, 16-04-97, R2.

Diagnosis: Habitus roller. Frontal ridge raised slightly from dorsal surface and formed by single well-defined line in smooth arc. Eye well-developed. Clypeal lobes small and inconspicuous. Pereonite 1 without deep furrow parallel to lateral margin (sulcus arcuatus). Dorsal surface of head and pereonites smooth. Posterior margin of pereonal epimeron 1 almost straight. Posterior lateral epimeron corner of pereonal epimeron 1 produced without kink at thickened lateral margin of epimeron at junction with inner lobe. Pereonal epimeron 2 subrectangular slightly pointed at anterior margin. Animal with white patches on along the side of animal, one on each pereonite.

Remarks: Two of the undetermined specimens of Buddelundia (C30895; C30907) are very similar to this species. Only a single specimen of each was collected and reliable determinations could not be made. B. albomaculata is also similar to Buddelundia species 7. Further work is necessary to determine the relationships among the undetermined material and the two species described here.

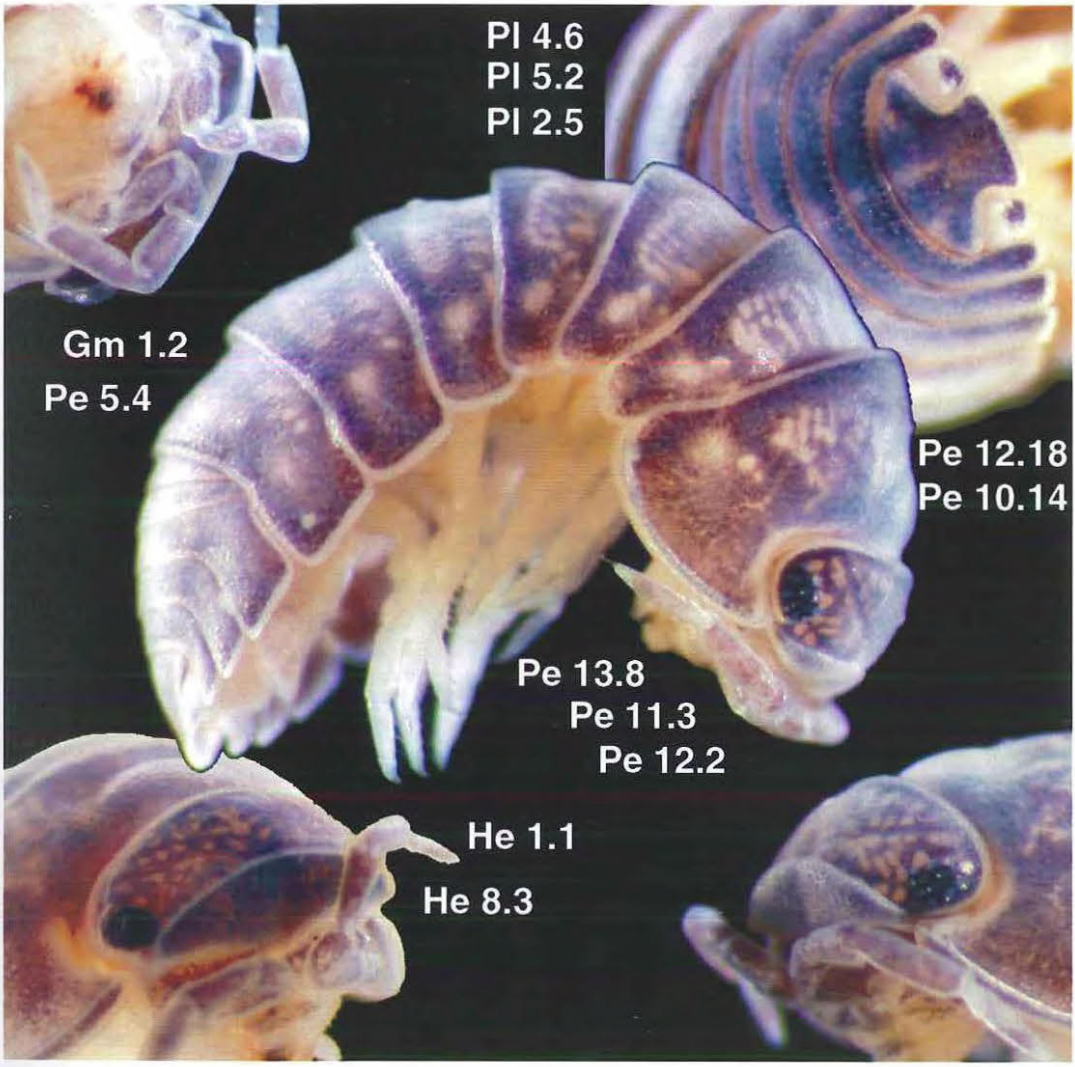


Plate 3.110. Buddelundia albomaculata **from Hillman Nature Reserve (C 30892) (length 5 mm).**

3.17.6.14. Buddelundia species 8

Plate 3.111.

MATERIAL EXAMINED: C31735, WILLIAM BAY NATIONAL PARK, -35.0000°S 117.2000°E, MCMILLAN, R. P., ??-03-88; C31736, TWO PEOPLES BAY, -34.9833°S 118.1667°E, NICHOLLS COLLECTION, ??-01-38; C31737, TORNDIRRUP NATIONAL PARK 9 KM S. OF ALBANY, -35.0900°S 117.8333°E, DYER, P. H. & LYON, J. L., 09-11-83, P1; C31738, LEDGE POINT, -35.0167°S 118.0328°E, HUMPHREYS, W. F. ET AL., 20-03-85; C31739, DENMARK, -34.9500°S 117.3500°E, WOMMERSLEY, W., ??-??-??, P1.

Diagnosis: Habitus roller. Animal convex. Frontal ridge formed by single well-defined line in smooth arc. Clypeal lobes small and rounded. Pereonite 1 without deep furrow parallel to lateral margin (sulcus arcuatus) but with wide and shallow depression. Posterior margin of pereonal epimeron 1 nearly straight. Posterior lateral epimeron corner of pereonal epimeron 1 produced without kink at thickened lateral margin of epimeron at junction with inner lobe. Inner lobe and posterior lateral epimeron border sub-equal in length. Pereonal epimeron 2 sub-rectangular. Dorsal surface of head and pereonites smooth. Animal without white spots on each pereonite at proximal lateral margin of each epimeron. Telson wider at distal border than at midpoint and rounded in appearance.

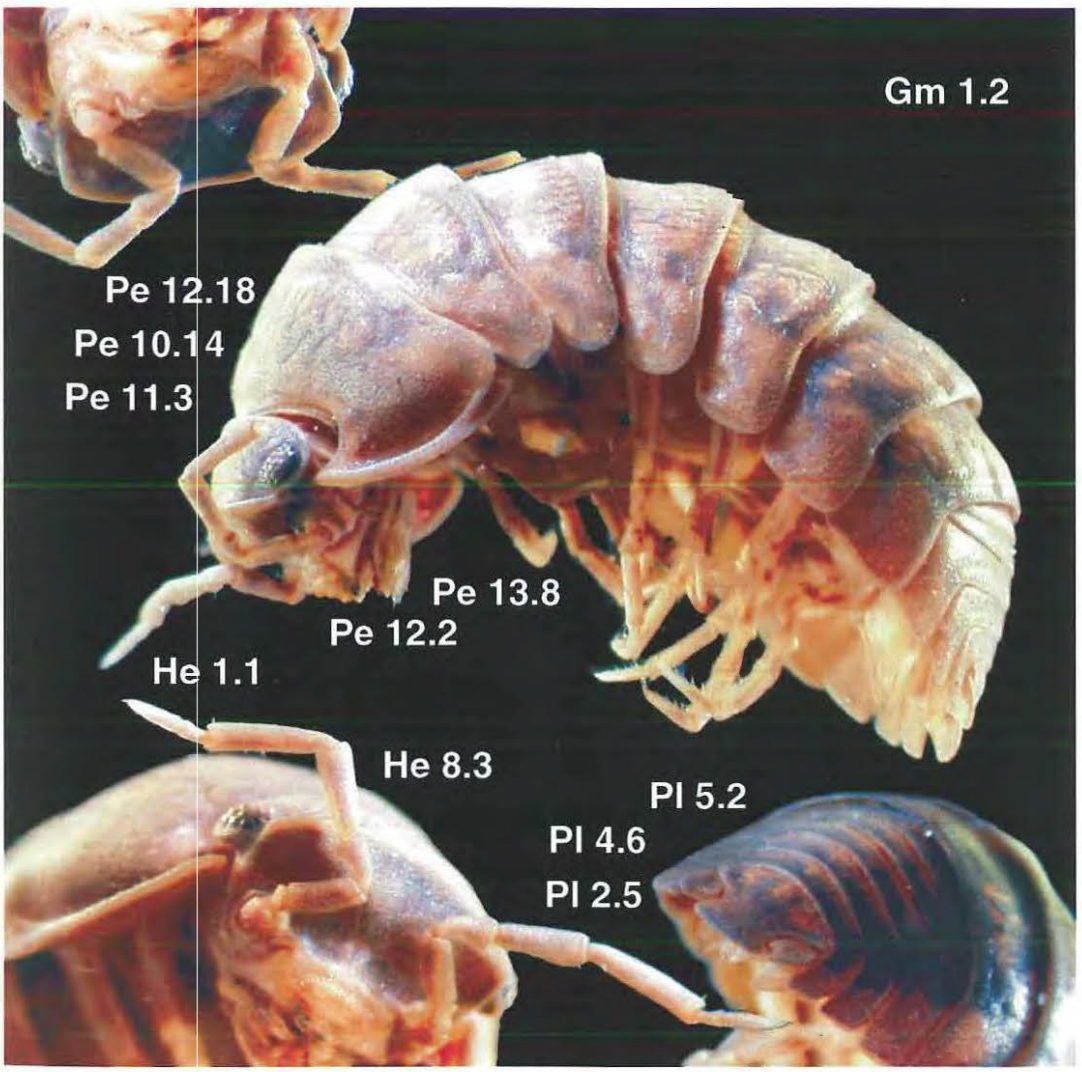


Plate 3.111. Buddelundia species 8 from Ledge Point (C31738) (length 8 mm).

3.18. MATERIAL NEEDING CONFIRMATION

The following material needs confirmation of identification following the allocation of new individual registration numbers. The old registration numbers represented a series containing more than one taxon. Therefore, the following specimens could be one of two or more taxon identified for tha range of registered specimens shown below.

MATERIAL EXAMINED: C2370/9, PEPPERMINT GROVE PERTH, -32 0000°S 115 7667°E, GLAUERT, L , ??-??-27, C5196/201, MANJIMUP, PERUP?, -34.3333°S 116.4500°E, GLAUERT, L., ??-03-36, G30; C1668/79, DANDARAGAN, -30.6667°S 115 7000°E, GLAUERT, L , ??-??-25; C2846/7, ROTTNEST ISLAND SERPENTINE LAKE, -32 0000°S 115.5000°E, GLAUERT, L., ??-09-28.

3.19. SUMMARY LIST OF TAXA

The following is a summary list of the taxa described in this Chapter and the number of records for each. The number of records for taxa determined only to family or genus is also given.

Table 3.4.
Summary list of taxa described in Chapter 3. The number of records for each taxon is given in the right hand column

		Number of Records
Infraorder Ligiamorpha		
Section Synocheta Legrand, 1946		
Family Ligiidae Brandt & Ratzeburg, 1931		
Ligia Fabricius,1798		
1	Ligia sp	2
Section Crinocheta Legrand, 1945		
Family Actaeciidae Vandel, 1952		
Actaecia Dana, 1853		
2	Actaecia pallida Nicholls and Barnes, 1926	12
Family Scyphacidae Dana, 1852		
Haloniscus Chilton, 1920		
3	Haloniscus searlei Chilton, 1920	67
Alloniscus Dana, 1856		
4	Alloniscus pallidulus Budde-Lund, 1885	10
Deto Guerin, 1836		
5	Deto marina Chilton 1884	6
Family Halophilosciidae Verhoeff, 1908		
Halophiloscia Verhoeff, 1908		
6	Halophiloscia couchi Kinahan, 1858	10
Family Armadillidiidae Brandt, 1833		
7	Armadillidium vulgare Latreille, 1804	30
Family Porcellionidae Brandt & Ratzeburg, 1831		
Porcellionides Miers, 1877		
8	Porcellionides pruinosus (Brandt, 1833)	130
Porcellio Latreille, 1804		2
9	Porcellio lamellatus Latreille, 1804	1
10	Porcellio scaber Latreille, 1804	47
11	Porcellio laevis Latreille, 1804	49
Section Synocheta Legrand, 1946		
Family Styloniscidae Vandel, 1952		
Notoniscus Chilton, 1915		
12	Notoniscus new species	4
Styloniscus Dana 1852		26
13	Styloniscus species 1	243
14	Styloniscus species 2	3
15	Styloniscus species 3	6
16	Styloniscus species 4	1
17	Styloniscus species 5	1
18	Styloniscus species 6	2
19	Styloniscus species 7	119

Table 3.4 (continued)

Section Crinocheta Legrand, 1945			
Family Platyarthridae Verhoeff, 1949 & Bathytropidae Vandel, 1952			
20	Platyarthridae species 1		54
21	Platyarthridae species 2		1
22	Platyarthridae species 3		36
23	Platyarthridae species 4		4
Australoniscus Vandel, 1973			
24	Australoniscus springetti Vandel, 1973		16
Family Oniscidae Latreille, 1802			3
Hanoniscus Budde-Lund, 1912			
25	Hanoniscus monodi Bowley, 1935		7
26	Hanoniscus nicholisi Bowley, 1935		9
27	Hanoniscus tuberculatus Budde-Lund, 1912		17
28	Hanoniscus new species		10
Family Philosciidae Kinahan, 1857			179
29	Philosciidae species 1	20	
30	Philosciidae species 2	7	
Eurygastor Vandel, 1973			
31	Eurygastor new species		39
Laevophiloscia Wahrberg, 1922			
32	Laevophiloscia species 1		312
33	Laevophiloscia species 2		345
Section Crinocheta Legrand, 1945			
Family Armadillidae Brandt & Ratzeburg, 1833			
Pseudodiploexochus Arcangeli, 1934			
34	Pseudodiploexochus species 1		40
35	Pseudodiploexochus species 2		90
36	Pseudodiploexochus species 3		1
Pseudolaureola Kwon, Ferrara & Taiti, 1992			2
37	Pseudolaureola new species 1		2
38	Pseudolaureola new species 2		3
39	Pseudolaureola wilsmorei (Nicholls & Barnes, 1926)		92
40	Pseudolaureola new species 3		10
41	Pseudolaureola new species 4		1
42	Pseudolaureola new species 5		4
Spherillo Dana, 1853			
43	Spherillo species 1		1
44	Spherillo species 2		106
45	Spherillo species 3		23
46	Spherillo species 4		69
47	Spherillo species 5		69
Acanthodillo Verhoeff, 1926			
48	Acanthodillo flavus (Budde-Lund, 1912)		9
49	Acanthodillo species 1		2
50	Acanthodillo species 2		10
51	Acanthodillo species 3		1
52	Acanthodillo species 4		3
53	Acanthodillo species 5		18
Cubaris Brandt, 1833			
54	Cubaris species 1		6
55	Cubaris species 2		11
56	Cubaris species 3		20
57	Cubaris species 4		3
Buddelundia Michaelsen, 1912			11
58	Buddelundia inaequalis Budde-Lund, 1912		133
59	Buddelundia cinerascens Budde-Lund, 1912		40
60	Buddelundia species 1		2
61	Buddelundia species 2		3
62	Buddelundia opaca Budde-Lund, 1912		62
63	Buddelundia species 3		3
64	Buddelundia species 4		41
65	Buddelundia species 5		16
66	Buddelundia species 6		31
67	Buddelundia species 7		130
68	Buddelundia nigripes Budde-Lund, 1912		114
69	Buddelundia nitidissima Budde-Lund, 1912		77
70	Buddelundia albomaculata Budde-Lund, 1912		5
71	Buddelundia species 8		5
Material yet to be determined			30
Total number of records			3152

3.20. TAXA AND DATA CONTRIBUTING TO SUBSEQUENT ANALYSES

The description and analysis in the remaining chapters of this thesis does not include littoral species, or species known to be introduced to the region (Taxa 1-11 in Table 3 4). Littoral species, in other words, specimens collected solely from littoral environments or belonging to littoral families, were not targeted as part of this study. Therefore, data for these species are scarce. Introduced taxa contributed only 0.0073% of the records generated from material collected during this study. Therefore, it is clear that they do not generally occur outside of urban and heavily modified landscapes. All species of the families Porcellionidae and Armadillidiidae were considered introduced as well as those previously identified as such by Bunn and Green (1982).

As this chapter has shown, the identification of many of the region's Oniscidea is uncertain both at the generic and species level. Consequently, non-littoral and non-cosmopolitan taxa are considered indigenous. Whether these are indigenous to the Region, to Western Australia, the Australasian region or the indo-pacific region cannot be determined at this stage.

As a whole, the dataset included 3152 records (Table 3.4). Indigenous mainland taxa, (taxa 12-71 in Table 3.4) contributed 2542 of these records. Thirty of these records were for specimens identified only to family or genus level. Therefore, the analysis in subsequent chapters is based upon 2512 records. However, in order to present a complete description of the terrestrial isopods of south-western Australia, the following section deals with introduced and littoral taxa.

3.21. REVIEW OF LITTORAL AND INTRODUCED TAXA

The following brief review is derived from literature and analysis of the WAM material. The introduced littoral species Halophiloscia couchii and Porcellio lamellatus and the indigenous Deto marina were reported from Rottnest Island by Bunn and Green (1982). It is now apparent that H. couchii (WAM material) and D. marina (Schmidt 2002a, this chapter) also occur on the shores of the Swan River estuary near Perth. The indigenous Actaecia pallida occurs throughout south-western Australia (Lewis & Green, 1994) but all of the specimens examined were from the Perth area. Specimens described by Budde-Lund (1912) as Alloniscus nicobaricus collected from Fremantle by Michaelsen in 1905 were examined and found to be consistent with the description of Alloniscus pallidulus Budde-Lund 1885 given by Green et al. (1990). A. pallidulus occurs along the Western Australian coast and in parts of south-east Asia (Green, et al., 1990) and was collected by the author from the shore of a coastal lagoon at the far north of the Swan Coastal Plain in the locality of Lesueur (Locality 202). At this same lagoon, the semi-aquatic Philosciidae species 2 was collected from saturated littoral sediment and from under

debris some 800 metres from the lake edge. Haloniscus searlei, which is widely distributed throughout the southern Australia (Williams, 1970), was recorded from a number of salt lakes on the Swan Coastal Plain and Rottnest Island (Locality 200). These are all old records and no microhabitat detail was available. The taxonomy and ecology of these secondarily or semi aquatic species merits further investigation particularly as high diversity is being found in such taxa in inland arid localities of Western Australia (Taiti & Humphreys, 2001). The specimen of Ligia from the Swan River estuary (Plate 3.41) constitutes the first record of the genus in south-western Australia. The genus Tylos has been recorded from west coast of Australia (Lewis, 1991) but has not been found in the region. In general, the region's littoral species of Oniscidea of are extremely poorly documented, even in the Perth locality.

The occurrence of the cosmopolitan Porcellio and Armadillidium appears to be a direct result of urbanisation and consequent modifications of the natural environment. Porcellio laevis is the most common introduced species in urban environments but it is not found outside of these areas. Porcellio scaber, Armadillidium vulgare and Porcellionides pruinosus are also present in urban environments but P. pruinosus was the only one of these found outside urban areas. It is been collected from some coastal parts of the Perth metropolitan area (WAM material) and was collected during this study in coastal conservation reserves in far northern part of the Swan Coastal Plain.

The occurrence of these synanthropic cosmopolitan taxa agrees with those previously recorded from Australia (Green, 1974; Bunn & Green, 1982). However, since only WAM material was examined and urban localities were not sampled as part of this investigation, it is very likely that there are other introduced synanthropic taxa present in the region. Green (1974) reported that P. laevis, despite being found in southern mainland Australia, does not occur in Tasmania. The fact that P. laevis is more common in the Perth locality than P. scaber, may be a result of a warmer climate. A. vulgare, which is of Mediterranean origin (Green, 1974), is also well established and widespread. The apparent absence of these species from natural landscapes is remarkable and merits further investigation. Given that these species are most likely very old introductions, probably dating back to colonisation, or perhaps early maritime exploration, and the species are now widespread in towns and cities, a number of hypotheses can be proposed. Firstly, the species are not able to tolerate seasonal dryness. Secondly, outside of cultivated parks and gardens, the organic matter produced by the native flora is not of sufficient nutritional quality and, thirdly, that non-indigenous species are not able to survive local fire regimes. Warburg (1965) noted that three species of Buddelundia have similar a thermo-tolerance to Armadillidium. This suggests that a combination of factors is the most likely explanation.

The following chapters present an ecological and historical biogeography of terrestrial isopods in south-westerm Australia.

CHAPTER 4

BIOGEOGRAPHY

4.1. INTRODUCTION

Chapter 3 described sixty species of indigenous terrestrial isopods. This chapter describes the biogeographical patterns created by the distributions of these taxa. Whittaker, Willis and Field (2001, p463) provided a useful analogy for the distributions of species when they stated "species range boundaries are more or less continuous envelopes containing far more spaces than objects". This is certainly true for terrestrial isopods in the south-western Australia. Whittaker et al. (2001) attributed the preponderance of holes within species range envelopes to a number of reasons. These were: (1) the existence of areas of suboptimal or unsuitable habitat; (2) temporal environmental variability; (3) impedance of species movements within landscapes; meaning that not all suitable habitats are occupied at any one time; and (4) the presence of interacting species. The information used to create the distributions and subsequent patterns in this chapter were extensive, the greater part collected systematically with the aim of providing a comprehensive geographical coverage, but it cannot be considered adequate to determine all of the "objects" within the species range "envelope". It can however provide fairly accurate indications of the extent of the likely scale of these envelopes and that, therefore, is the principal objective of this chapter.

This chapter also considers the role that microhabitat plays in the determination of the species distributions. The next chapter examines some of the factors, operating at a range of scales, responsible for patterns of species diversity of terrestrial isopods within the region. These two analyses will facilitate, later in the thesis, an examination of the first three factors, unsuitable microhabitat, temporal environmental variability and landscape constraints to the movement of species within the landscape, considered by Whittaker et al. (2001) to be responsible for the nature of the species range envelope.

Judd & Horwitz (2003) dealt with the distribution and microhabitat utilisation of twenty-seven of the sixty taxa shown here. This chapter expands on that paper by detailing all the taxa, including two new taxa recognised after its preparation, adding two patterns, and by providing a more detailed synthesis of microhabitat utilisation. Distributions and microhabitat data are explored and underlying reasons for the resulting patterns are discussed. Given the importance of observational information that I highlighted in the taxonomic review in Chapter 3, this Chapter captures some of my key observations where they might otherwise have been lost.

The purpose of this chapter is to establish a framework for assessing whether the biogeography of terrestrial isopods reflects existing patterns from the region. It aims to:

- determine principal biogeographical patterns within the region and their scale;
- assess the degree to which endemism is explained by the patterns; and to
- establish likely contributing factors to the distributional patterns, including the role of microhabitat utilisation.

4.2. EXPLANATION AND SUMMARY OF THE PATTERNS

Rather than presenting only selected or conforming taxa, the distributions of all 60 indigenous taxa are shown. Six biogeographical patterns were recognised and, in addition, taxa occurring at single localities and those with distributions not matching any of the six patterns are described as two separate groups. The patterns themselves are preceded by a summary table (Table 4.3) showing the number of taxa forming each pattern, the geographic scale at which each taxon was distributed, the nature of the data for each pattern and a broad summary of the microhabitat data for the taxa contributing to each pattern. The patterns are then described, illustrated (Figures 4.1 – 4.29) and discussed.

To aid description of the biogeographical patterns in this chapter distributions have been classified at a series of geographical scales. Just as important as the patterns themselves, is the scale or scales at which contributing taxa were distributed. The recognition of distributional scale is also useful in highlighting links between microhabitat utilisation within the various patterns. The scales given here are a modification of those used in Judd and Horwitz (2003). An additional scale was necessary because this chapter includes single locality taxa not included by Judd and Horwitz (2003). The scales are defined, from smallest to largest, in Table 4.1. Two important components underpin the development of these intuitive scales. These are the geographical unit at which the data were collected and collated, namely the locality (see Subsection 2.3.1 and Glossary Section 2.9) and the bioregions shown in Figure 1.4. The bioregions represent the most accepted regionalisation to date and serve, in the absence of regions more relevant to terrestrial isopods at this stage, as the most appropriate biogeographical framework upon which distributions may be assessed. The purpose of the next chapter is to assess species diversity at a range of scales. These scales in conjunction with the biogeographical patterns presented in this chapter are used in Chapter 6 to construct a preliminary biogeographical model.

Table 4.1.
Names, abbreviations and definitions of the scales used to classify the distributions of the sixty indigenous mainland Oniscid taxa forming the biogeographical patterns.

Scale Name	Abbreviation	Definition
Single Locality	(SL)	A taxon with a distribution entirely within a single locality
Restricted	(RD)	A taxon occurring within 2, 3 or 4 adjacent localities and not separated by more than one locality.
Local	(LO)	A taxon distributed in within a part of a bioregion but may have a few outliers in an adjacent bioregion
Sub-regional	(SR)	A taxon distributed widely throughout one or two bioregions with only occasional outliers in the third bioregion.
Regional	(RL)	A taxon distributed widely throughout all bioregions.

As outlined at the conclusion of Chapter 3 (Section 3.20), the data set of indigenous taxa consisted of 2512 records. Of these, 494 had no microhabitat data and 680 were records from pitfall traps. Therefore, 1338 records provided the microhabitat data analysed in conjunction with the patterns. The patterns are illustrated by a series of distribution maps and corresponding summarised and graphed microhabitat data. The number of records for each taxon is indicated on each distribution map following the species name. The points on the individual distribution maps represent the number of sites at which a taxon was found. This does not necessarily equal the number of records for that taxon because there were often multiple records from a single site. Graphs were generated from the proportion of the total number of records used for the distribution maps that had microhabitat data. They show either the microhabitat utilisation of a single taxon or a number of taxa, dependent upon the amount of data available and what was required to best illustrate the utilisation for a pattern.

Coded microhabitat data were given, where present, in the lists of material examined in Chapter 3. These are described in the last two columns of Table 4.2. The data have been summarised twice in this chapter. Firstly, into generic categories for inclusion in a summary table of the patterns (Table 4.3) and, secondly, into more revealing categories for the graphs that accompany the distribution maps. The generic summary is shown in the first column of Table 4.2 and the summaries used in the graphs are shown in the second column. The raw microhabitat data for each taxon given in Chapter 3 are shown in Appendix 2. Appendix 2 links this chapter with the previous one by showing the raw microhabitat data and the page number of the lists of material examined, which is where the geographical raw data for each taxa can be found. It also provides a breakdown of the nature of records for each taxon.

The concordant distribution of at least three taxa were considered to represent a biogeographical pattern. A summary of the patterns determined, the number of contributing taxa, the nature of records and microhabitat data grouped into generic categories is shown in Table 4.3. Regional Patterns are composed simply of species distributed widely throughout the region and in all bioregions. Forest patterns are composed of species found only in forested areas, usually the Jarrah Forest and Warren Bioregions, but some taxa have outliers in wooded areas of the Swan Coastal Plain Bioregion. High Rainfall Patterns were composed of taxa whose distributions fall entirely within, or within and in close proximity to, the 1000 mm annual isohyet. Northern patterns are composed of taxa found only in the northern half of the region. Single Locality Patterns group all the species found only within one locality (as defined earlier in Subsection 2.3.1). These taxa are related in no other way but treating the group a whole allows for comparisons to be made among them. Eastern Patterns are composed of taxa found in the far east (or outside) of the Jarrah Forest Bioregion either to the east of, or in close proximity to, the 600 mm annual isohyet. South Eastern patterns comprised taxa

found only in the south east of the region. Unclear patterns examine the remaining taxa whose distributions did not fit the previous five patterns.

Table 4.2.
Microhabitat codes used in the lists of material examined in Chapter 3 and Appendix 2. The first column shows the generic category used in Table 4.3 and the second column shows the groupings used in microhabitat graphs (Figures 4.1 - 4.29) in this chapter.

Generic Category	Categories in Graphs in this Chapter	Codes in Appendix 2 and Chapter 3	Microhabitat Description
Litter	Unspecified Litter	L10	Litter of unspecified type
"	"	L50	Litter under vegetation
"	"	L70	Acacia spp. litter
"		E1	Abundant in epigean microhabitats
	Litter with logs	L20	Litter in association with logs
"	Litter with rocks	L30	Litter in association with rocks
"	Riparian litter and sediment	L60	Litter in a riparian situation, from a riparian species
"	"	L80	Organic sediment
"	"	L90	Litter in, on or under sedges or rushes
"	Litter at the base of a tree	L40	Litter at the base of a tree (unspecified)
"	Bark litter	L41	Litter at the base of a tree (E. diversicolor)
"	"	L42	Litter at the base of a tree (E. wandoo)
Logs	Under logs	G10	Unspecified log microhabitat
		G30	Under a log or on the underside of a log
	Inside logs	G20	Inside a log
"	Under bark on logs	G40	Under bark on log
"		G50	Under moss on logs
Bark	Under bark on trees	B10	Under shedding bark (E. diversicolor)
"	"	B20	Under shedding Bark (E. wandoo)
"	"	B30	Under riparian Bark (Melaleuca sp., E. rudis)
"	"	B40	Under unspecified non-shedding bark
		B50	Up skirt of grass tree
Rocks	Under rocks	R1	Under unspecified rock type
"	"	R2	Under granite or similar crystalline rock
"	"	R3	Under laterite rock
"	"	R4	Under limestone rock
"	"	R5	Under concrete or other debris
Other	In soil	S1	In soil, all types except organic sediment
"	Miscelleneous	A1	Unspecified aquatic habitat
"	"	A2	In saltwater
"	"	A3	In fresh water
"	"	U1	Urban, in gardens etc.

Table 4.3.
A summary of the biogeographical patterns, with the contributing taxa and their distributional scales, and a summary of the nature of records and microhabitat data. Abbreviations for scales were defined in Table 4.1.

Biogeography			Records				Generic Microhabitat Category				
Pattern	Taxa	Scales	n	Pitfall Traps	Without Data	With Data	Litter	Logs	Bark	Rocks	Other
Regional	5	RE	841	238	112	491	65%	24%	4%	4%	2%
Forest	6	SR, LO	536	62	78	396	48%	37%	10%	3%	2%
High Rainfall	14	SR, LO, RD	258	25	64	169	47%	15%	36%	0%	2%
Northern	12	SR, LO	829	315	167	147	35%	21%	14%	25%	5%
Eastern	4	LO	13	0	3	10	30%	30%	10%	30%	0%
South Eastern	3	LO, RD	11	4	4	3	33%	0%	0%	66%	0%
Single Locality	9	SL	25	1	7	17	71%	12%	18%	0%	0%
Unclear	7	SR, LO, RD	199	35	59	105	49%	19%	10%	9%	13%
Total	60		2512	680	494	1338	52.6%	25.8%	12.0%	6.3%	3.1%

In order to examine whether there was a difference in the microhabitat utilisation of widely distributed species in different parts of the region, the data for some taxa included in regional and forest patterns were examined separately according to whether the specimen occurred in the Warren Bioregion or elsewhere. Microhabitat graphs for these species show the individual data for both these parts of the region and for the region as a whole.

Each of the six patterns is now described and allocated a separate section. Each section includes comment about the contribution of that pattern to the overall species richness of the region. These comments are drawn from the data collected during the fieldwork conducted during this study and provide a background to the analysis of species diversity that follows in the next chapter. The names of the 120 localities and the 3 supplementary localities are used in the description of patterns throughout this Chapter. A map showing the localities was shown in Figure 2.2 and the corresponding names given in Table 2.1. The numbers of localities are given in parentheses where necessary. The bioregions of the Swan Coastal Plain, the Jarrah Forest and the Warren, illustrated in Figure 1.4, are used as a ground plan for describing distributions. Where they are mentioned in the following sections, the terms Jarrah Forest, Swan Coastal Plain and Warren refer to the Bioregions. The outline of the study area (the three bioregions) combined, along with each 200 mm annual isohyet, is shown on all distribution maps.

In Chapter 3 I highlighted that anecdotal and observational information in the literature was useful in understanding microhabitat utilisation within the region. For this reason I have included personal observations in this chapter where I think they help illustrate a particular point. I have also presented the microhabitat data as graphs rather than undertaking frequency analysis. Such analyses were investigated but they were problematic in that the generalist taxa are numerous and occur in many different microhabitats while the specialists are scarcer and occur in only a few. The number of

observations in an individual cell of a chi-square table for example, was is either to few when examining specialists or swamped by the numbers of microhabitat generalists and therefore made the test meaningless. It was possible to avoid this by selecting taxa but then there was the likelihood of manufacturing a statistic to suit an argument.

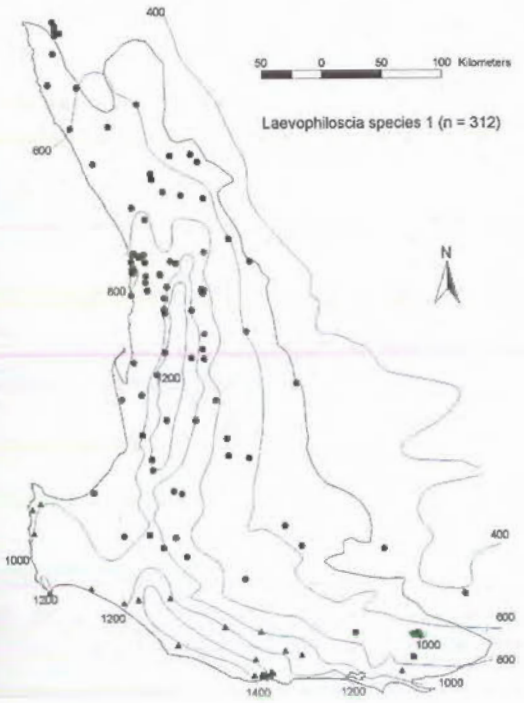
4.3. REGIONAL PATTERNS

Very few taxa were distributed throughout the region: only five were found to have widespread distributions. In all but one taxon, leaf litter appeared very important and it accounted for 65% of the records. Logs were also important (24%) and the remaining microhabitat types accounted for only 10% of the records (Table 4.3).

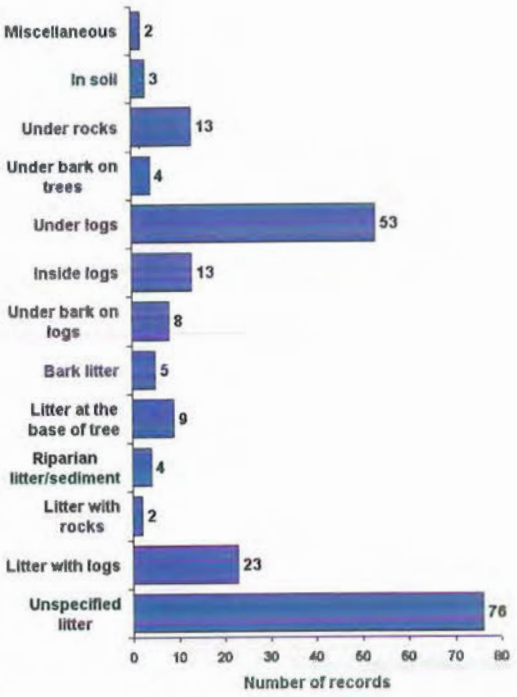
Laevophiloscia species 1 (Figure 4.1) and Laevophiloscia species 2 (Figure. 4.2) were both widespread but had differing distributions and microhabitat utilisation patterns. They were both common in leaf litter, but particularly species 2, which was less common in drier areas. Both species were collected frequently from litter in association with logs and appear to be mobile as they were also well represented in pitfall traps (Appendix 2). The more widely distributed, and morphologically diverse, species 1 was more common in the seasonally dry, north-eastern parts of the jarrah forest and was twice as common with logs. This suggests that logs may be important in extending the distribution of this species into drier parts of the region.

Indeed, there is a marked sub-regional variation in the microhabitat utilisation of both Laevophiloscia species 1 and species 2. The utliastion of leaf litter by both species varied between the Warren Bioregion compared to elsewhere. Forty-nine percent of the records for Laevophiloscia species 1 from the wetter Warren localities came from litter microhabitats while from outside the Warren this fell to 29.0% (Appendix 2). This was not true for the less widespread Laevophiloscia species 2 which showed very little variation in its use of litter microhabitats throughout the region. It seemed equally dependent upon litter in all parts of the region.

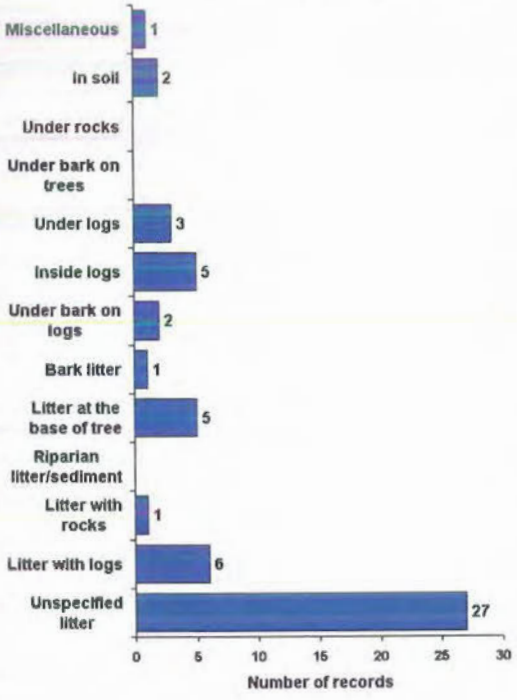
Although there is a notable outlier of species 2 at Mount Lesueur (Locality 202) in the far north of the region (Figure 4.2), the absence of Laevophiloscia species 2 from drier localities in the northeast of the region is probably explained by its dependence upon leaf litter and lesser utilisation of logs. It appears to be principally a litter-dweller in wetter parts of the region with an incidental occurrence in other microhabitats consistent with a very mobile species. It is a conspicuous component of forest litter in heavily wooded and wetter parts of the region. The presence of Laevophiloscia species 1 in drier localities may be a result of its differing morphologies permitting a greater array of microhabitat utilisation rather than a dependence on leaf litter and high mobility. In drier localities, logs are more likely to retain moisture for longer (Brown et al., 1996) and thus provide refugial microhabitat to a greater extent than leaf litter alone.



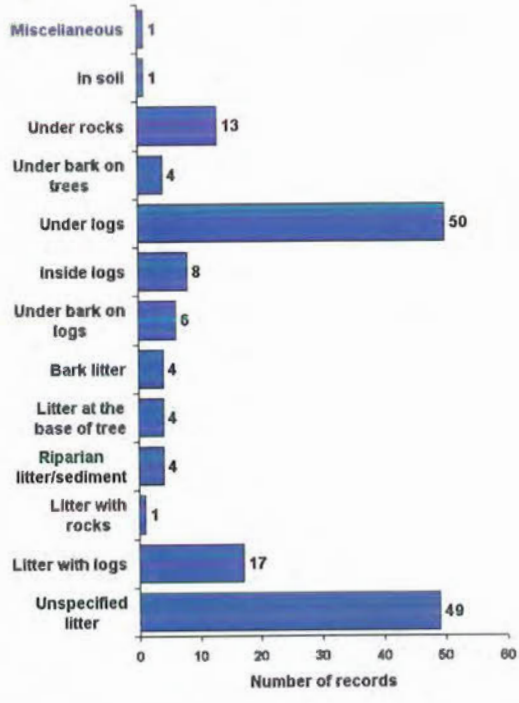
Regional scale distribution of Laevophiloscia species 1. Of the 312 records, 75 were from the Warren Bioregion (▲) and 237 from elsewhere (●).



Total microhabitat utilisation for Laevophiloscia species 1.

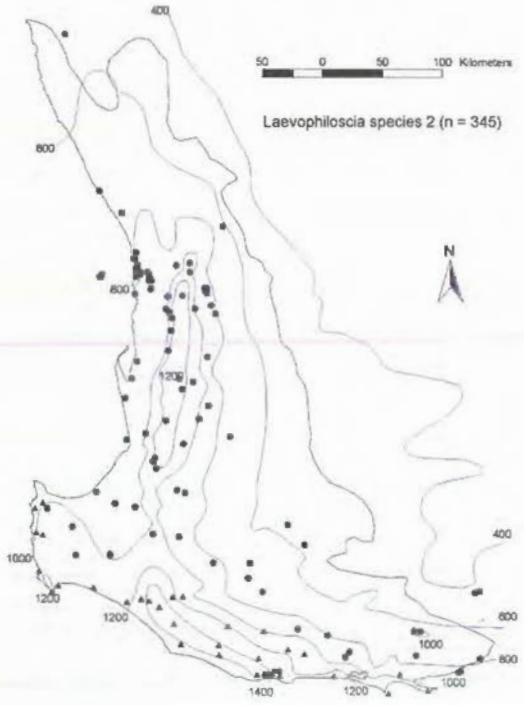


Microhabitat utilisation for Laevophiloscia species 1 within the Warren Bioregion.

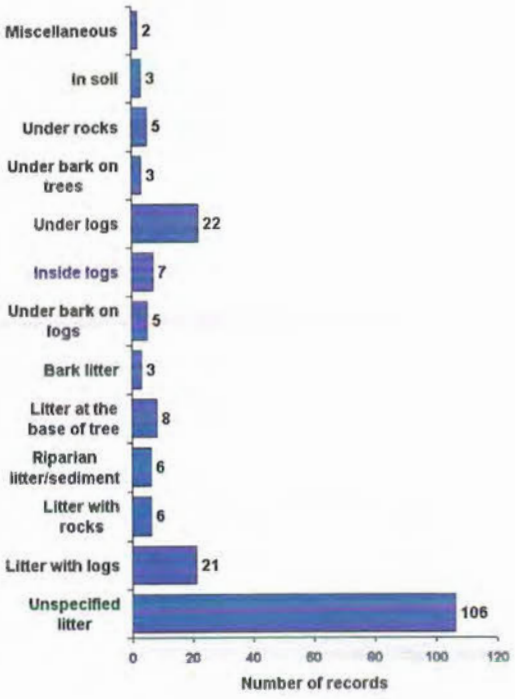


Microhabitat utilisation for Laevophiloscia species 1 outside the Warren Bioregion.

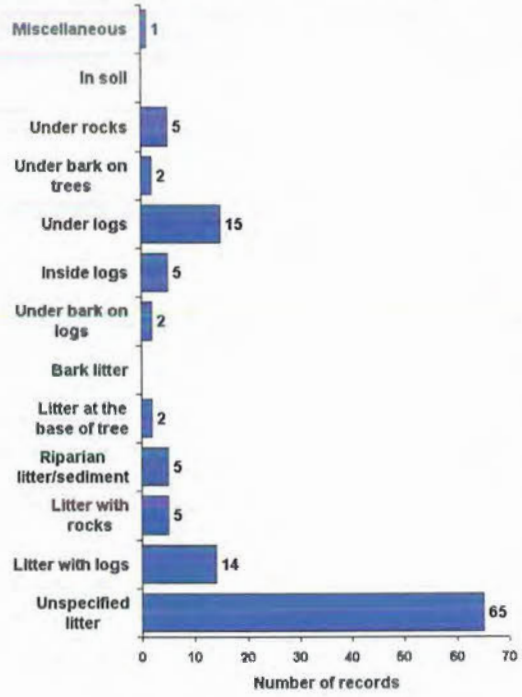
Figure 4.1. The regional scale distribution and microhabitat utilisation of Laevophiloscia species 1 forming part of Regional Patterns.



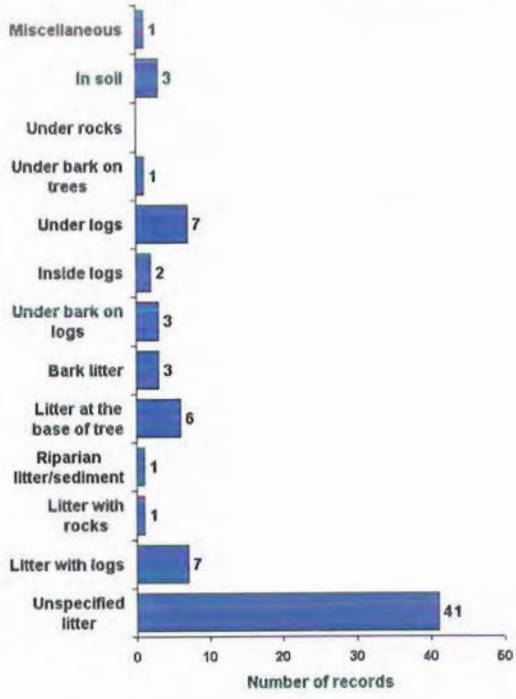
Regional scale distribution of Laevophiloscia species 2. Of the 345 records, 217 were from the Warren Bioregion (▲) and 128 from elsewhere (●).



Total microhabitat utilisation for Laevophiloscia species 2.



Microhabitat utilisation for Laevophiloscia species 2 within the Warren Bioregion.

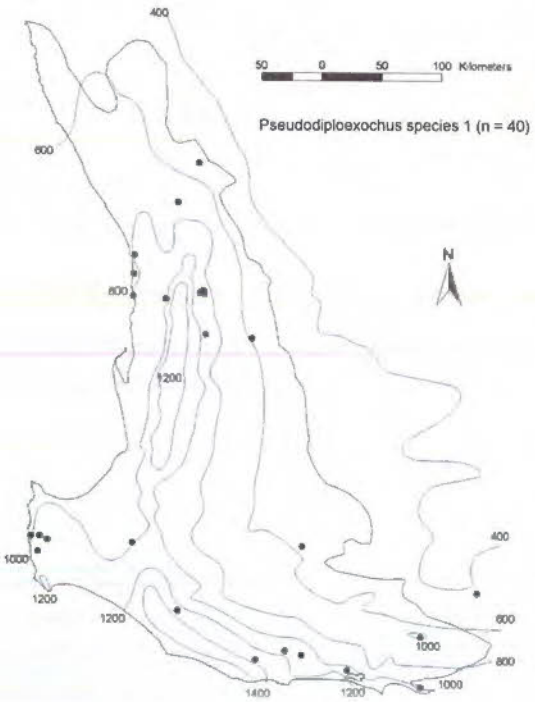


Microhabitat utilisation for Laevophiloscia species 2 outside the Warren Bioregion.

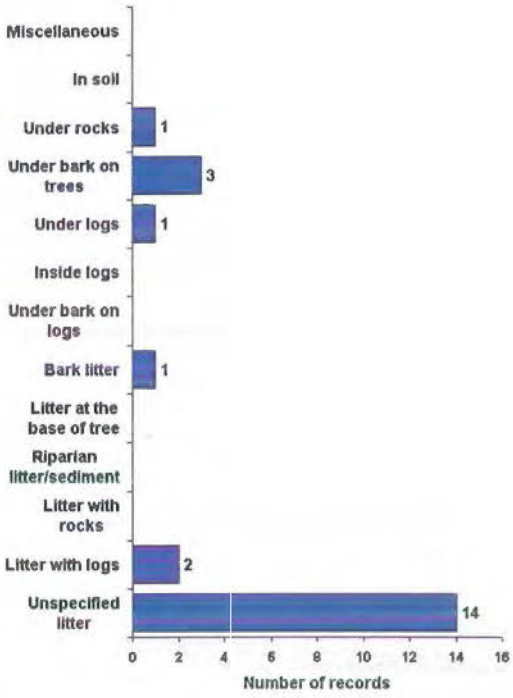
Figure 4.2. The regional scale distribution and microhabitat utilisation of Laevophiloscia species 2 forming part of Regional Patterns.

Laevophiloscia is a significant component of the litter-dwelling fauna and was present at 85% of the sampling sites listed Appendix 1a, with species 1 and species 2 co-occurring frequently at the same site but in different microhabitats. It is a significant contributor to regional species richness. Increased taxonomic resolution within these two species complexes will permit a greater understanding of the relationship between morphology, microhabitat utilisation and the ability to persist in seasonally dry localities. What are now regional patterns are probably a mixture of regional, sub regional, high rainfall and locally distributed patterns. The task of redescribing and describing Laevophiloscia from Western Australia is an arduous one. However, a cladistic analysis combined with distributional data would be extremely useful in developing a historical biogeography. The Laevophiloscia complexes are likely to be the result of vicariance, colonisation and local incipient speciation.

Pseudodiploexochus species 1 and species 2 (Figure 4.3) were also litter dwellers distributed widely throughout the region. However, both were largely absent from the central Jarrah Forest, suggesting clear north and south groupings in both species. Apart from the presence of these two groups, the overall distributional patterns were similar to the litter-dependent Laevophiloscia species 2. In common with most regionally distributed taxa, both species were collected frequently by pitfall traps (Appendix 2). Since these species are very small (< 3 mm long), it is not surprising that many of the records from leaf litter came from Berlese funnels. Their small size also suggests that it is likely that these species could have been overlooked in structurally complex microhabitats. A small size suggests also that dispersal occurs at very small scales and only in conditions where there is spatial and temporal continuity in leaf litter distribution. The degree of tuberculation on the dorsal surface of the pereonites varied greatly within Pseudodiploexochus species 2. This was apparent not only between sites but also within samples in wetter forest localities. As this is an important character in determining species within this genus (Taiti & Ferrara, 1979), it is probable that the regional distribution of Pseudodiploexochus species 2 represents a complex of localised endemics. While the genus appears to be regionally distributed, increased taxonomic resolution of species 1 and 2 is likely to be useful in further highlighting small-scale distribution patterns within the region. The occurrence of distinctive Pseudodiploexochus species 3 at a single site in the wet jarrah forest provides evidence of this. The regional distribution of Pseudodiploexochus species 2 is probably the result of a complex of overlapping locally distributed species and restricted endemics. Small-scale vicariance events, resulting from changes in leaf litter distribution (e.g. fires), are likely to create local extinctions and incipient speciation. Such events are probably important historical determinants of the distribution of this species complex.

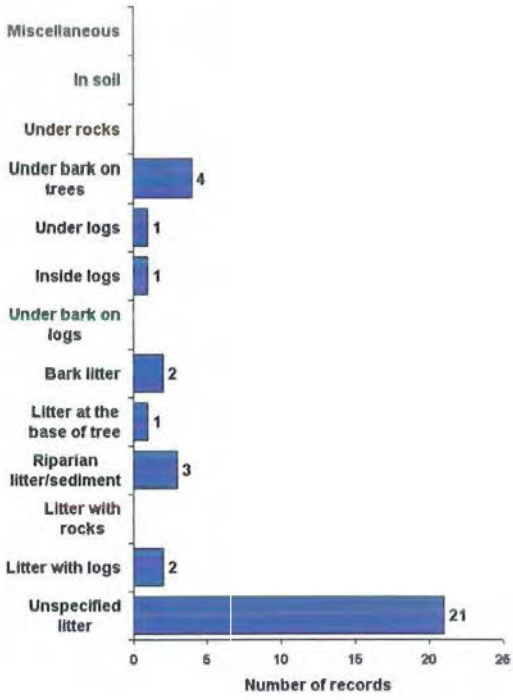


Regional scale distribution of Pseudodiploexochus species 1.



Total microhabitat utilisation for Pseudodiploexochus species 1.

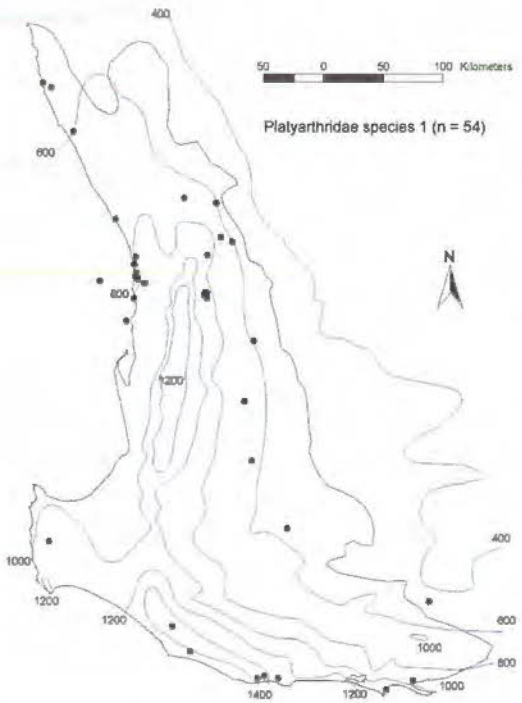
Regional scale distribution of Pseudodiploexochus species 2.



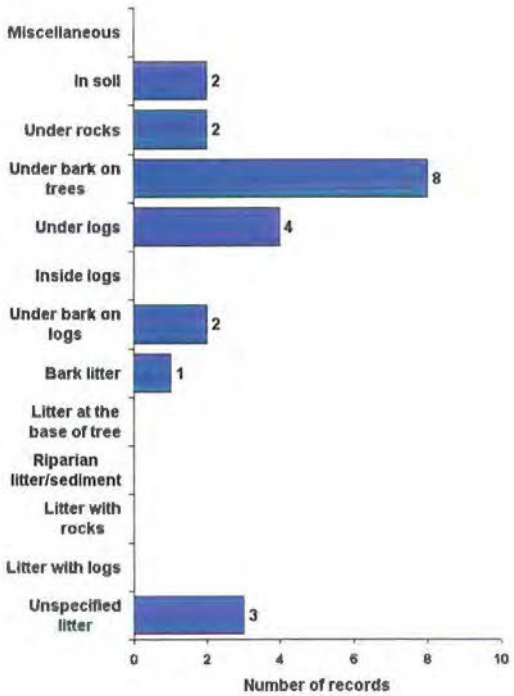
Total microhabitat utilisation for Pseudodiploexochus species 2.

Figure 4.3. The regional scale distributions and microhabitat utilisation of Pseudodiploexochus species 1 and species 2 forming part of Regional Patterns.

Platyarthridae species 1 (Figure 4.4) differed in its distribution and microhabitat utilisation from all other regionally distributed taxa. It was found much more frequently in the eastern drier areas and was absent from much of the wetter forest areas, particularly in the jarrah forest. Its prevalence in pitfall traps matched those of the other taxa, as just over a quarter of records came from piffall traps (Appendix 2). However, in contrast to other regionally distributed taxa, it appeared less dependent upon leaf litter. Records were distributed evenly among major microhabitat types with tree bark and logs appearing the most significant. The whitish appearance and small eyes of the Platyarthridae suggests an endogean existence and, globally, many species are known from endogean microhabitats often with ants (Hopkin, 1991). The collection of more specimens from under rocks, logs and in soil, than from litter, reinforces this notion. Its small size and tendency to occupy cryptic microhabitats suggest that it may have been under-collected. Therefore, the actual distribution may be more extensive than that given in Figure 4.4. In a similar manner to Pseudodiploexochus, the presence of the species may have been overlooked. However, despite its small size, the whitish colour and lack of conglobating ability makes the species easier to see, and therefore collect, than Pseudodiploexochus. Its presence in the epigean environment, and therefore the likelihood of its being collected during this study, would have been dependent upon local moisture conditions.



Regional scale distribution of Platyarthridae species 1.



Total microhabitat utilisation for Platyarthridae species 1.

Figure 4.4. The regional scale distribution and microhabitat utilisation of Platyarthridae species 1 forming part of Regional Patterns.

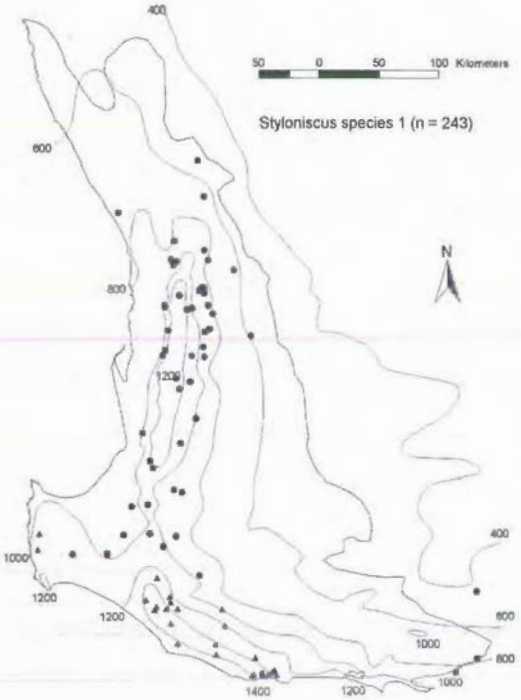
Regionally distributed species are fundamentally important to the regional species richness. At sites with low richness they were usually the only taxa found and at sites with high richness they were always present. Their broad geographical distribution can be attributed to a number of factors. Firstly, they appear to be mobile, particularly Laevophiloscia, secondly they appear to be able to utilize a range of microhabitat types and, finally, their small size, in the case of Pseudodiploexochus species 1 and 2 and Platyarthridae species 1, allows them to utilise highly cryptic moist refuges. This combination of traits allows them to persist after local disturbance. As was mentioned for Laevophiloscia and Pseudodiploexochus, further taxonomic discrimination of these species would dramatically enhance the clarity of the regional biogeography.

4.4. FOREST PATTERNS

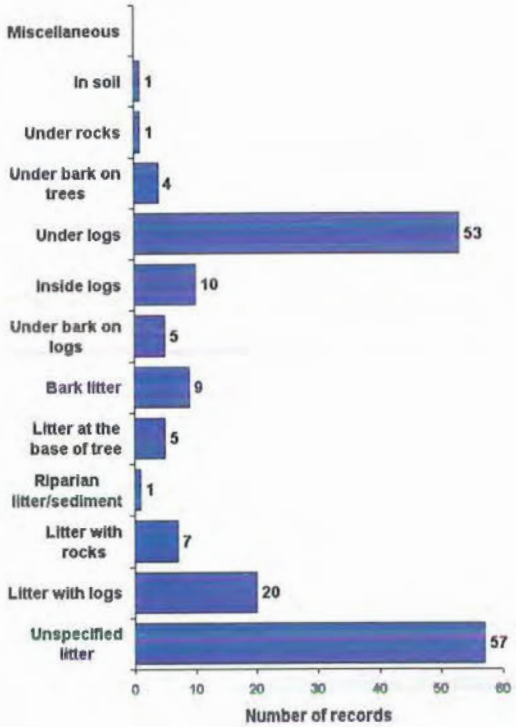
Forest patterns are represented by five sub-regionally distributed taxa and one locally distributed taxon. The taxa are considered sub-regionally distributed because they are all largely absent from the Swan Coastal Plain. There were isolated occurrences of some of these taxa within the Bioregion but all are in the Perth area. In common with the regionally distributed taxa, many records (Table 4.3, 48%) came from leaf litter. Forest taxa however, showed much greater utilisation of logs (Table 4.3, 37%) and much less of an occurrence in pitfall traps. Occurrence under bark was also prevalent although this was mainly accounted for by a few taxa in the Warren.

Two species of Styloniscus were widely distributed throughout the Warren and Jarrah Forest. The distribution of Styloniscus species 1 (Figure 4.5) coincides very well with forested localities and, apart from its absence from the Swan Coastal Plain, its distribution pattern is similar to that of Laevophiloscia species 2. Its microhabitat utilisation was also similar. It was collected mainly from leaf litter and was well represented in pitfall traps (Appendix 2). In common with Laevophiloscia species 2 it showed little sub-regional variation in leaf litter utilisation. It was equally well represented in leaf litter in both the Warren and elsewhere. In the Warren, it was a conspicuous component of karri bark litter but was rarely found under karri bark.

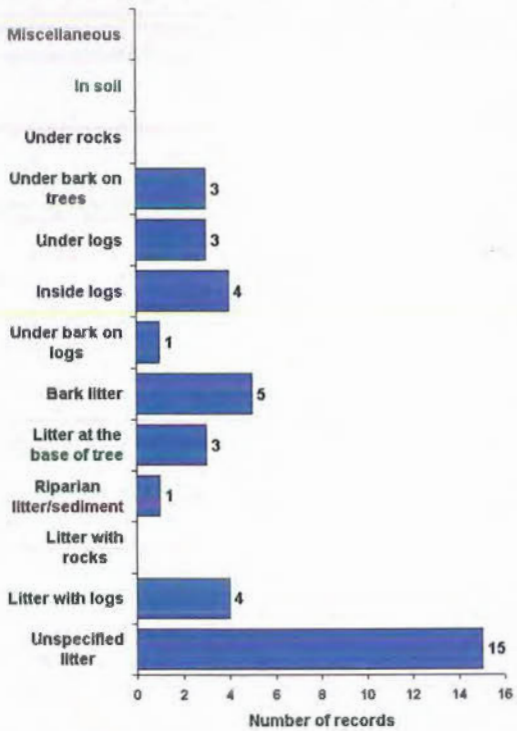
Styloniscus species 1 differed from Laevophiloscia species 2 in that in drier forest areas it was much more prevalent with logs. In this respect it is similar to Laevophiloscia species 1 but Styloniscus species 1 is far less widespread and is confined mostly to forested areas over 800 mm annual rainfall. All the records for Styloniscus species 1 from pitfall traps come from outside the Warren, suggesting that it is possibly more mobile in drier areas.



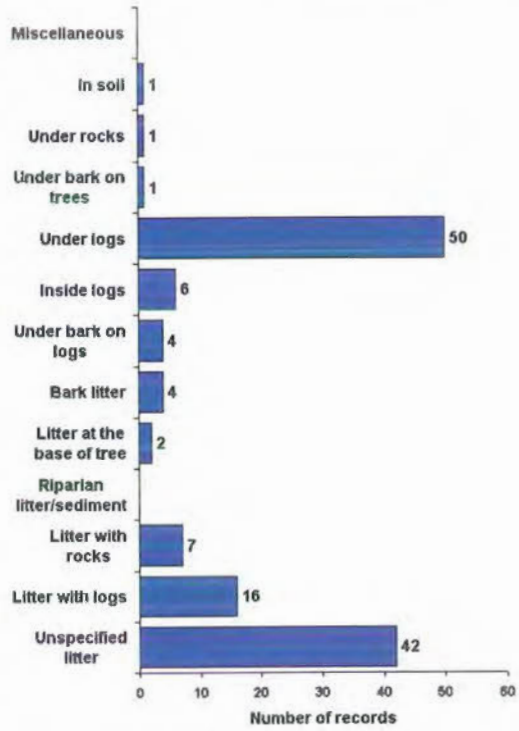
Sub-regional scale distribution of Styloniscus species 1. Of the 243 records, 186 were from the Warren Bioregion (▲) and 57 from elsewhere (●).



Total microhabitat utilisation for Styloniscus species 1.



Microhabitat utilisation for Styloniscus species 1 within the Warren Bioregion.

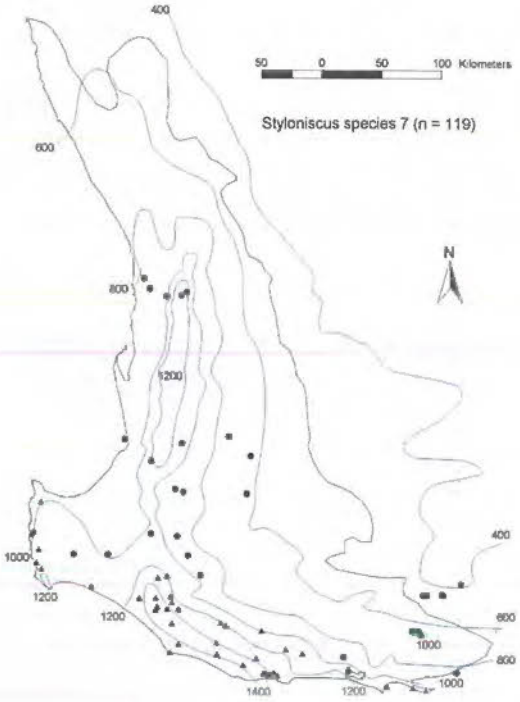


Microhabitat utilisation for Styloniscus species 1 outside the Warren Bioregion.

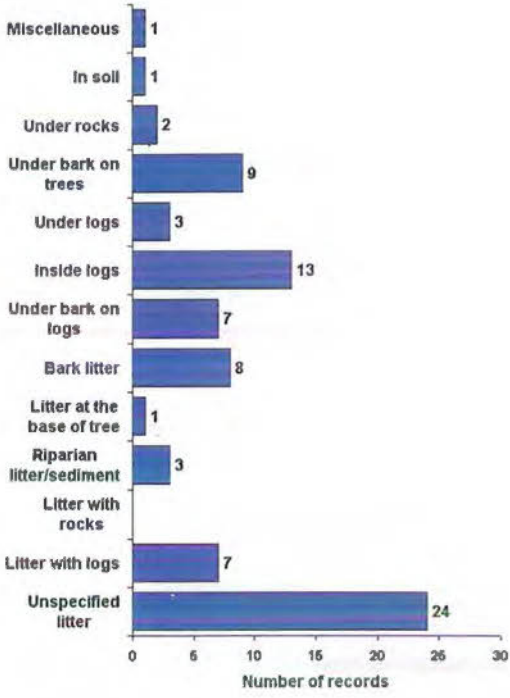
Figure 4.5. The sub-regional scale distribution and microhabitat utilisation of Styloniscus species 1 forming part of Forest Patterns.

The sub-regional scale distribution of Styloniscus sp. 7 (Figure 4.6) differs subtly from both Styloniscus species 1 and Laevophiloscia species 2. Compared to these species, it was much less common in the higher rainfall localities of the Jarrah Forest and much less frequently collected from pitfall traps (Appendix 2). While both species Styloniscus species 1 and 7 were common in leaf litter, the reliance of species 7 on all categories of leaf litter was much less in the Warren than elsewhere. Of all the regionally or sub-regionally distributed taxa, Styloniscus species 7 was the most common inside logs. This is predominantly in the Warren and is in direct contrast to Styloniscus species 1. Styloniscus species 7 appears to be present predominantly in wet localities of forest but is much more common and morphologically diverse in the wet, organic-rich Warren, particularly in karri bark litter and under karri bark. Despite some old records from the Perth (Locality 21) and Fremantle (Locality 25) localities, it is absent from northern forests and very infrequently encountered in the high rainfall parts of the Jarrah Forest.

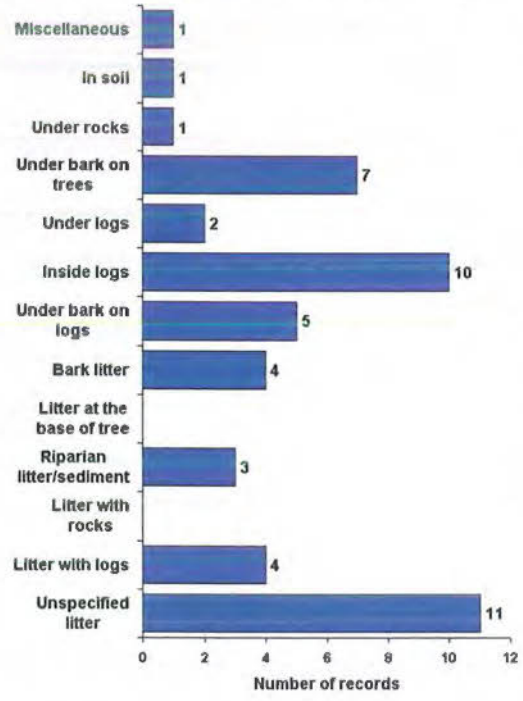
The most widely distributed of the Armadillidae was the regionally distributed Spherillo species 5 (Figure 4.7). A notable feature of its distribution is the distinct north/south split also evident in Pseudodiploexochus; an issue that will be explored more fully at the end of this chapter in Section 4.11 and in Chapter 8. It occurred in most of the forested districts but, in common with the regionally distributed Laevophiloscia species 2 and the forest dweller Styloniscus species 7, it was absent from the far northern part of the Jarrah Forest. The northern part of its distribution overlapped with a similar species, Spherillo species 4 (See Northern Patterns, Section 4.7). Its wide geographical distribution may be explained by the fact that it was well represented in all microhabitat types. These characteristics, and the fact that it was remarkably less common in the wetter litter of the Warren, suggest that it is capable of tolerating seasonally dry conditions. Whilst largely epigean throughout most of the forest localities, the species was much more arboreal in the karri forest. Occurrence under karri tree bark accounted for 69% of records in the Warren (Figure 4.7). Since the species is capable of surviving in forest that is very dry seasonally, its presence under bark, above the forest floor, may be a response to very wet conditions. Association with logs, a notable feature of most forest taxa, was also significant with this species. Twenty-four percent of records were collected from logs, most of these from under the bark in the Jarrah Forest. This phenomenon was most pronounced with jarrah logs, which shed bark in a laminar fashion providing a smooth unimpeded substrate between the log and the bark. Clearly, this widely distributed species is mobile and capable of utilising a range of microhabitats. It is remarkable that no specimens at all were collected from pitfall traps (Appendix 2).



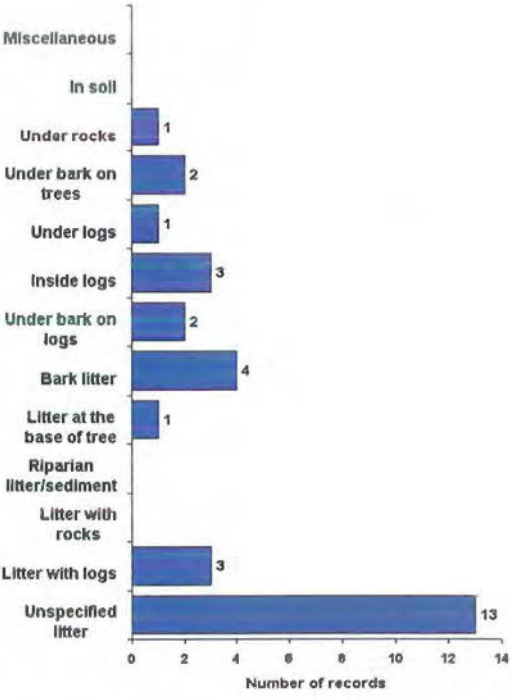
Sub-regional scale distribution of Styloniscus species 7. Of the 119 records, 76 were from the Warren Bioregion (▲) and 43 from elsewhere (●).



Total microhabitat utilisation for Styloniscus species 7.

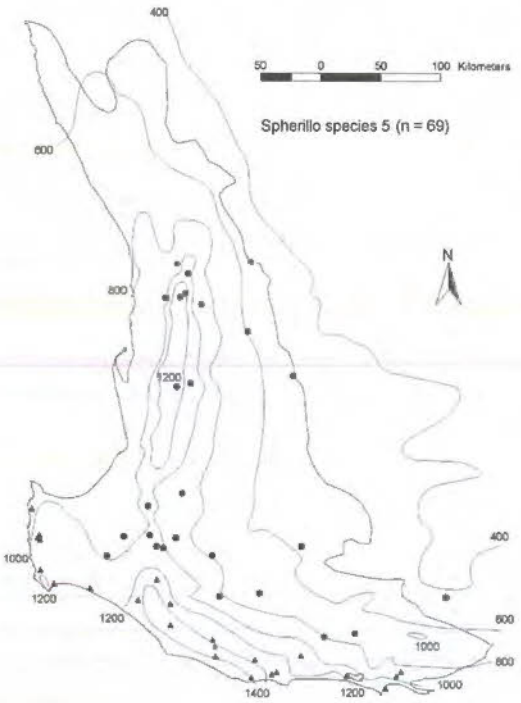


Microhabitat utilisation for Styloniscus species 7 within the Warren Bioregion.

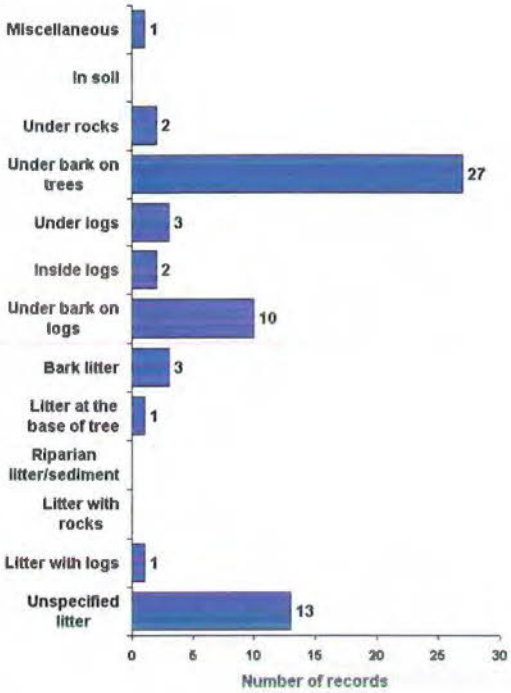


Microhabitat utilisation for Styloniscus species 7 outside the Warren Bioregion.

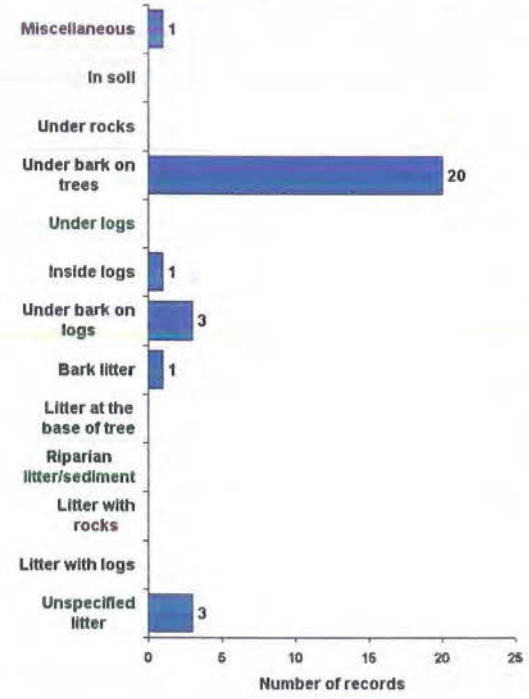
Figure 4.6. The sub-regional scale distribution and microhabitat utilisation of Styloniscus species 7 forming part of Forest Patterns.



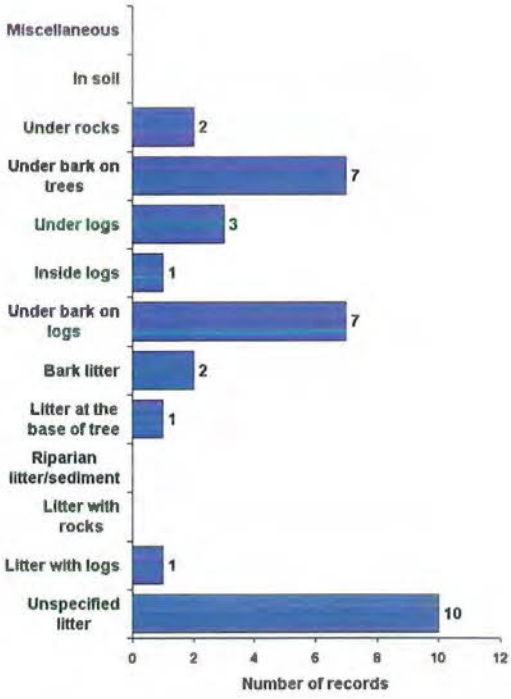
Sub-regional scale distribution of Spherillo species 5. Of the 69 records, 38 were from the Warren Bioregion (▲) and 31 from elsewhere (●).



Total microhabitat utilisation for Spherillo species 5.



Microhabitat utilisation for Spherillo species 5 within the Warren Bioregion.

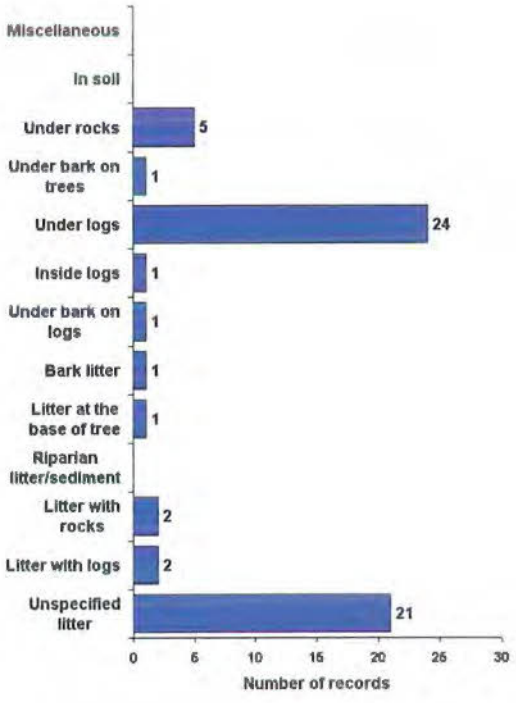


Microhabitat utilisation for Spherillo species 5 outside the Warren Bioregion.

Figure 4.7. The sub-regional scale distribution and microhabitat utilisation of Spherillo species 5 forming part of Forest Patterns.

In contrast to the regional forest patterns illustrated so far, Buddelundia nitidissima (Figure 4.8) appears to be a xeric species. Although widely distributed, it was largely restricted to the Jarrah Forest, particularly drier eastern localities from which most other forest taxa were absent. Its principal microhabitat utilisation was in leaf litter and under logs on the forest floor. There are very few records from localities recording over 1000 mm annual rainfall and only a single record, dating from 1928, from the Swan Coastal Plain. Budde-Lund described this species from eight type localities, six of these being single specimens (Budde-Lund, 1912, p.32). Some type localities are within the distributions of other species of Buddelundia described here. It is likely that B. nitidissima, as described by Budde-Lund, represents more than one species. It may be, however, that it is now absent from a part of the region where it was once common. The Swan Coastal Plain has open woodlands similar to those found in the east of the Jarrah Forest and receives similar rainfall. The fact that B. nitidissima occurs sporadically throughout the Jarrah Forest Bioregion, and is common at the eastern margin of the Swan Coastal Plain, makes this hypothesis worthy of further investigation. Urbanisation and the fragmentation of woodlands and periodic removal of substantial logs and leaf litter by frequent fire and other disturbances would be more than capable of making this species locally extinct on the Swan Coastal Plain.

Sub-regional scale distribution of Buddelundia nitidissima.

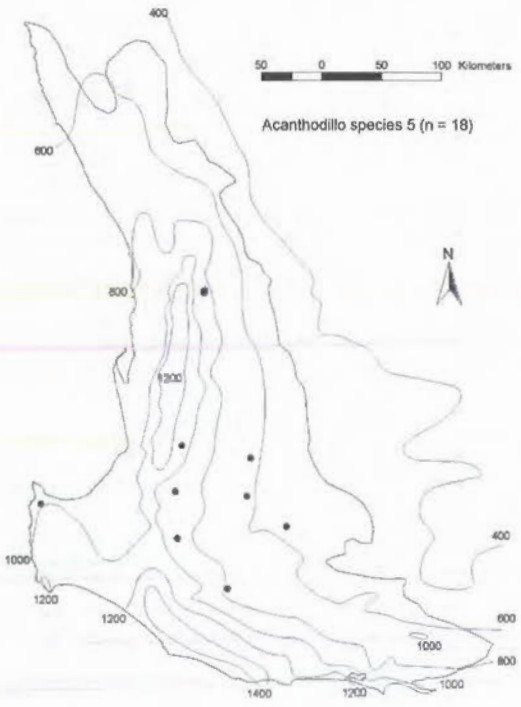


Total microhabitat utilisation for Buddelundia nitidissima.

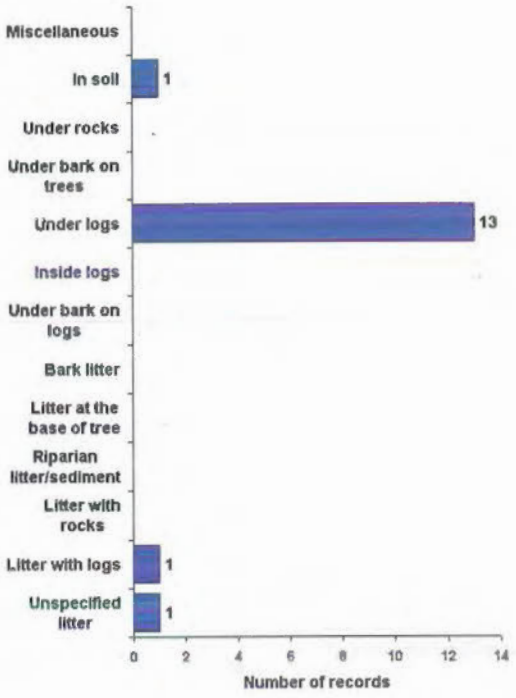
Figure 4.8. The sub-regional scale distribution and microhabitat utilisation of Buddelundia nitidissima forming part of Forest Patterns.

The importance of logs, and a lesser dependence upon leaf litter, in drier localities of the jarrah forest (previously indicated by Laevophiloscia species 1, Styloniscus species 1 and B. nitidissima) is highlighted further by the sub-regionally distributed Acanthodillo sp. 5 and the locally distributed Acanthodillo sp. 2 (Figure 4.9). Both species were found entirely within the jarrah forest, mostly from under logs. Acanthodillo species 2 was found with logs, under rocks, in soil and in bark litter but was absent from leaf litter. As well as logs, Acanthodillo species 5 had a single record from soil, leaf litter and leaf litter associated with logs. Lewis (1989) noted that this genus occurs frequently with ants or termites. However, despite an obvious tendency for at least a partial endogean existence, neither of these two species were collected from the nests of ants or termites.

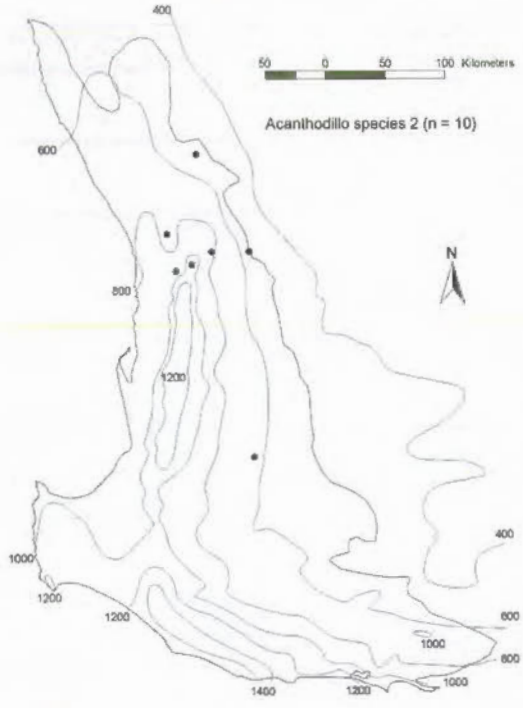
Forest taxa are important to patterns of regional taxa richness. Forested areas producing litter and logs increase dramatically the taxa richness when compared to non-forested areas. Forest taxa are found mainly in the central and southern forests and are usually found with regional taxa. The presence of forest taxa in all but northern parts of the region accounts for significant differences in taxa richness. The presence of forest taxa is dependent upon site conditions. Sites with all microhabitat types, such as large logs, litter and mature trees of which bark is utilised (e.g. karri, marri & wandoo), are more likely to contain a greater range of forest taxa.



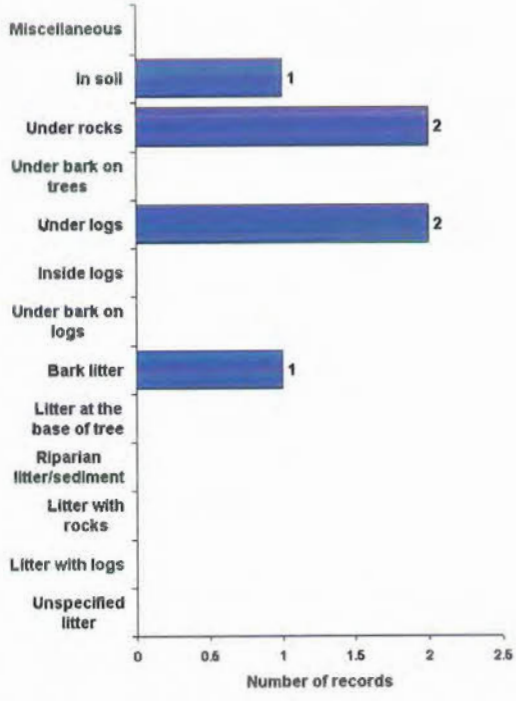
Sub-regional scale distribution of Acanthodillo species 5.



Total microhabitat utilisation for Acanthodillo species 5.



Local scale distribution of Acanthodillo species 2.



Total microhabitat utilisation for Acanthodillo species 2

Figure 4.9. The sub-regional scale distribution of Acanthodillo species 5, the local scale distribution of Acanthodillo species 2 and microhabitat utilisation of both species forming part of Forest Patterns.

4.5. HIGH RAINFALL PATTERNS

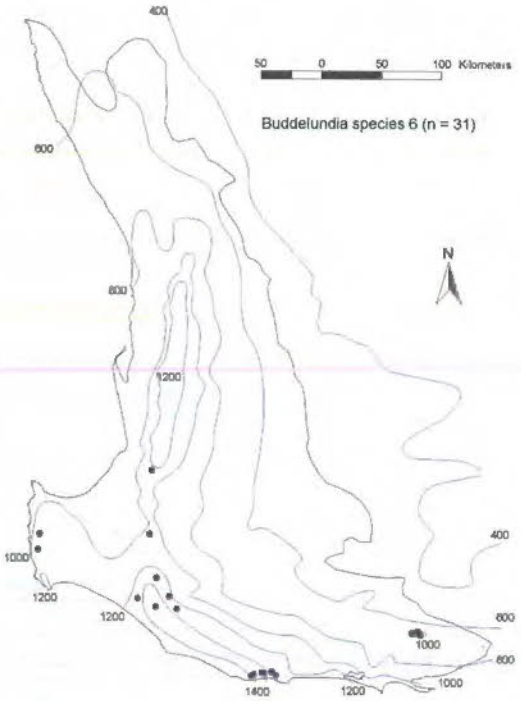
High rainfall patterns are composed of 14 taxa, the most for any pattern. The pattern consists of two sub-regional scale distributions extending northward from the Warren, five local scale, three restricted scale, one sub-regional scale distribution within the Warren and two local scale and one restricted scale distributions within the wetter Jarrah Forest. Obviously, given the restricting influence of high rainfall, the scales of distributions are smaller than those of forest taxa. All high rainfall taxa occurred in forested ecosystems and are, to some extent, smaller scale, forest patterns. Therefore, their description follows Forest Patterns.

As a group, high rainfall taxa had an almost identical occurrence in leaf litter to forest taxa (Table 4.3). However, dependence upon leaf litter increased as the scale of the pattern became smaller. High rainfall taxa occur mainly in the Warren and this is reflected in the fact that their presence under tree bark (Table 4.3, 36%) was significantly more than that of forest taxa (Table 4.2, 10%).

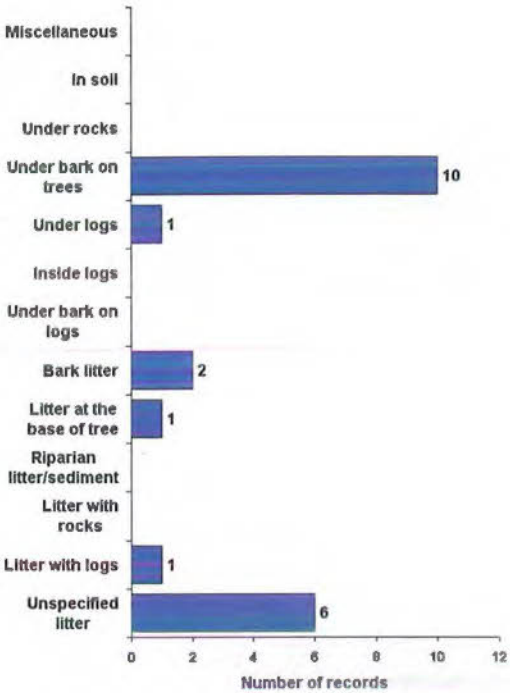
Taxa found in the Warren were, with one exception, different from, though closely related to, those found in the wetter Jarrah Forest. No taxa occurred throughout the entire high rainfall part of the region, but the sub-regionally distributed Buddelundia species 6 (Figure 4.10), which had four discrete distributions within the Warren, also occurred at two outlying sites in high rainfall Jarrah Forest. It was found equally, and almost exclusively, in litter and under bark. Platyarthridae species 3 (Figure 4.10) had a similar distribution pattern but, unlike Buddelundia species 6, it extended northward in heavily wooded coastal localities. It was also most common in leaf litter and under tree bark but was also found with logs.

Pseudolaureola wilsmorei (Figure 4.11) was the most widely distributed of the local scale species. It was not found outside the Warren and, although widespread, it was clustered into four groups of sites in a similar manner to Buddelundia species 6. It appears to be relatively mobile since it was collected from pitfall traps (Appendix 2) and was found in all other microhabitat types occupied by high rainfall taxa. Nevertheless, leaf litter and under tree bark were by far the most common microhabitat utilised.

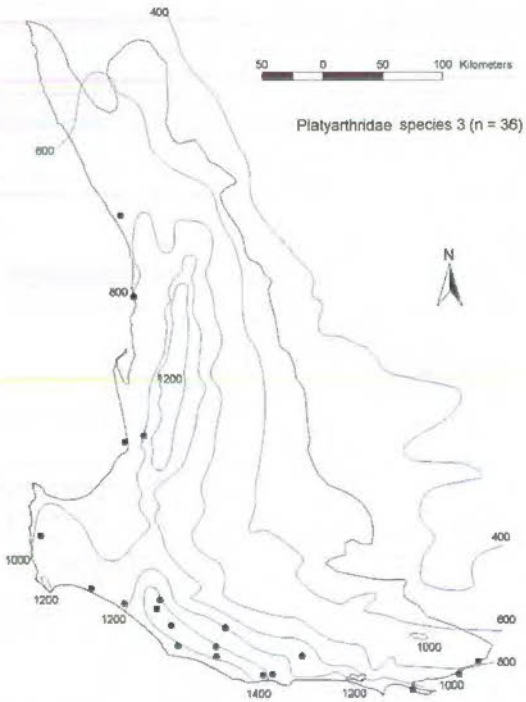
The distributional pattern of the groupings within the Warren Bioregion shown by Buddelundia species 9 and P. wilsmorei is also evident in the Geocrinia complex of frogs (Wardell-Johnson & Roberts, 1996).



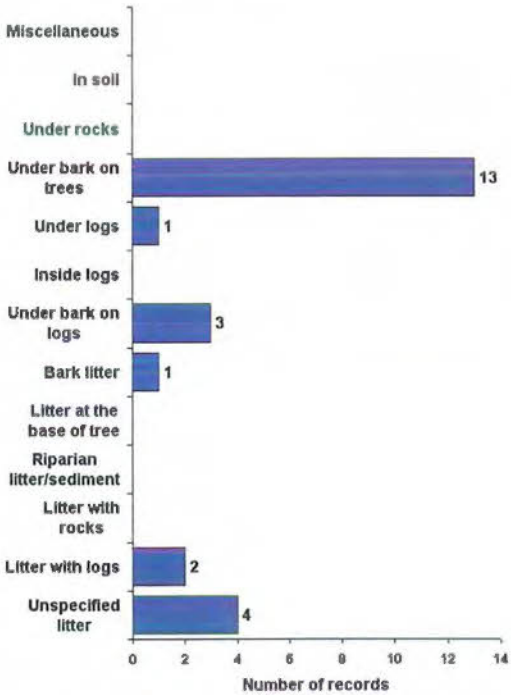
Sub-regional scale distribution of Buddelundia species 6.



Total microhabitat utilisation for Buddelundia species 6.

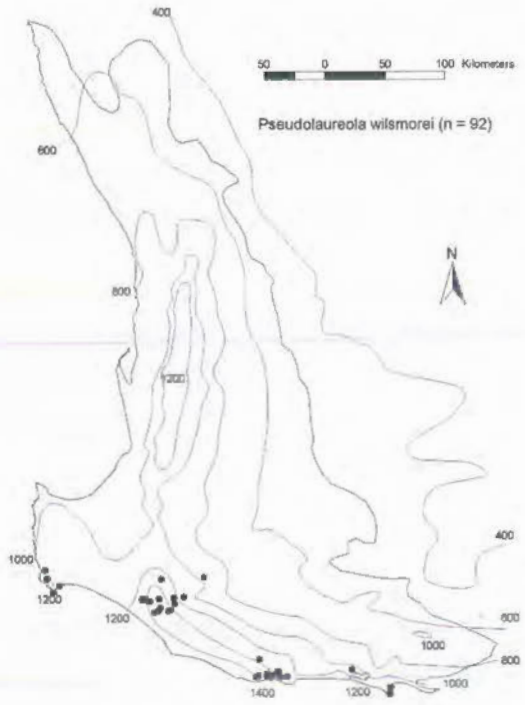


Sub-regional scale distribution of Platyarthridae species 3.

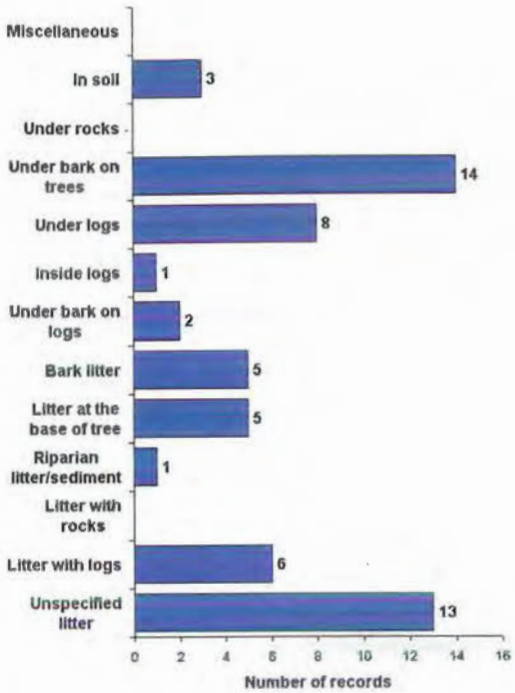


Total microhabitat utilisation for Platyarthridae species 3.

Figure 4.10. The sub-regional scale distributions and microhabitat utilisation of Buddelundia species 6 and Platyarthridae species 3 forming part of Forest Patterns.



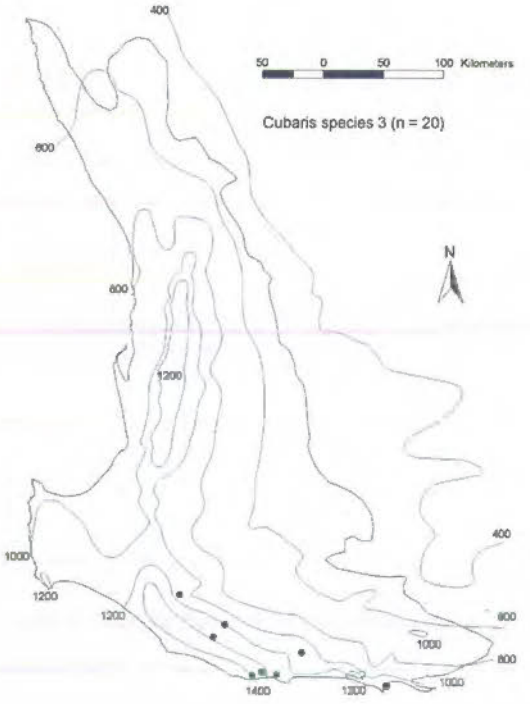
Local scale distribution of Pseudolaureola wilsmorei.



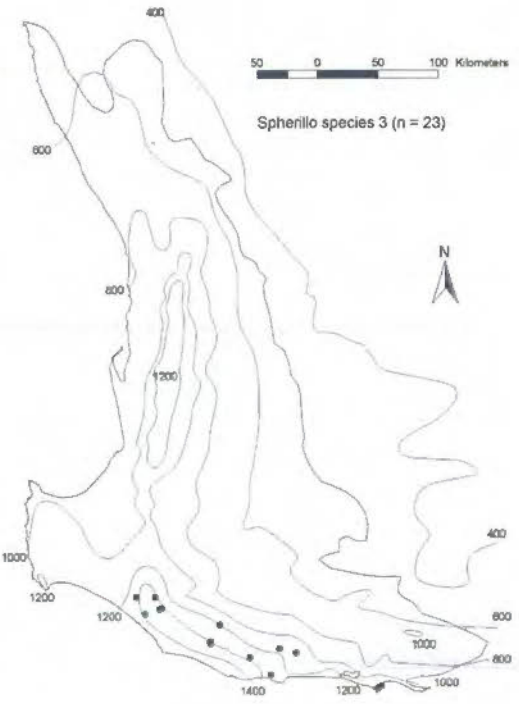
Total microhabitat utilisation for Pseudolaureola wilsmorei.

Figure 4.11. The local scale distribution and microhabitat utilisation of Pseudolaureola wilsmorei forming part of High Rainfall Patterns.

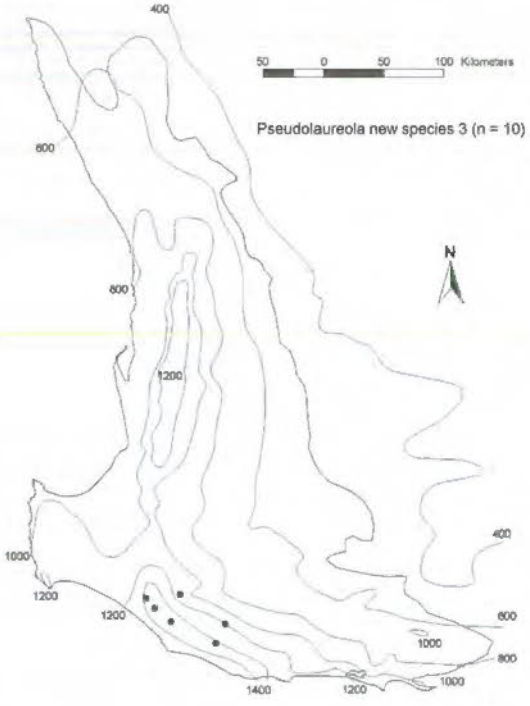
Spherillo species 3, Cubaris sp. 3 and Pseudolaureola new species 3 (Figure 4.12) were distributed widely within the central part of the distribution of karri trees. The distribution of Spherillo species 3 is slightly more widespread than that of Cubaris species 3 and Pseudolaureola species 3. Cubaris species 3 was notably absent from the Charnwood (Locality 88) and Pemberton (Locality 89) localities, which are at the centre of most of the locally distributed high rainfall taxa. Microhabitat data for the three species are similar and have been combined in Figure 4.12. They were very common under karri bark, but it is interesting to note that the more widely distributed Spherillo species 3 was more prominent in leaf litter (Appendix 2) than Cubaris species 3 (Appendix 2) and was also represented from pitfall traps. Throughout the region Spherillo is much more widespread than Cubaris. Pseudolaureola new species 3, the most restricted of the three species, co-occurred with P. wilsmorei in the central part of its range. It was more dependent upon leaf litter than P. wilsmorei, Spherillo species 3 or Cubaris sp. 3. In common with P. wilsmorei, both Spherillo species 3 and Cubaris species 3 were associated with logs. Curiously, Cubaris species 3, which, occurred more frequently under karri bark, was not collected from karri bark litter (Appendix 2).



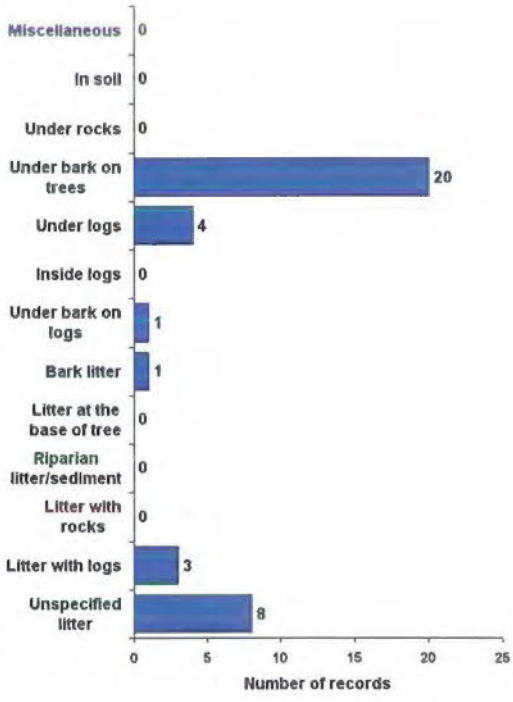
Local scale distribution of Cubaris species 3.



Local scale distribution of Spherillo species 3.



Local scale distribution of Pseudolaureola new species 3.



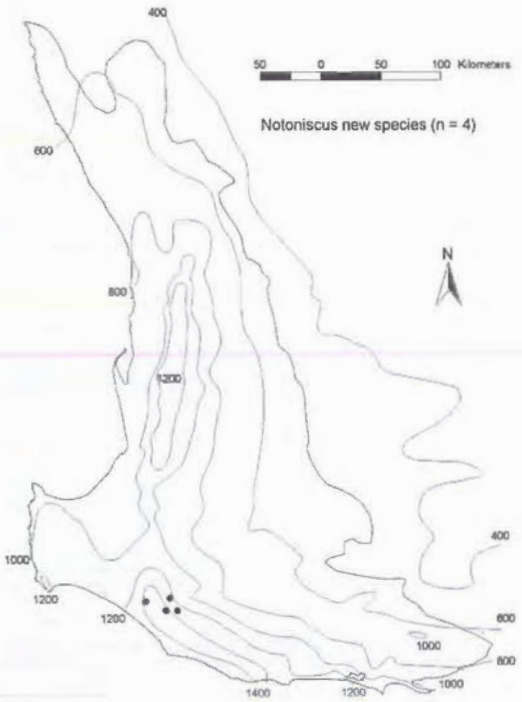
Combined total microhabitat utilisation for Cubaris species 3, Spherillo species 3 and Pseudolaureola new species 3.

Figure 4.12. The local scale distributions and combined microhabitat utilisation of Cubaris species 3, Spherillo species 3 and Pseudolaureola new species 3 forming part of High Rainfall Patterns. Raw data for species microhabitat utilisation are tabulated in Appendix 2.

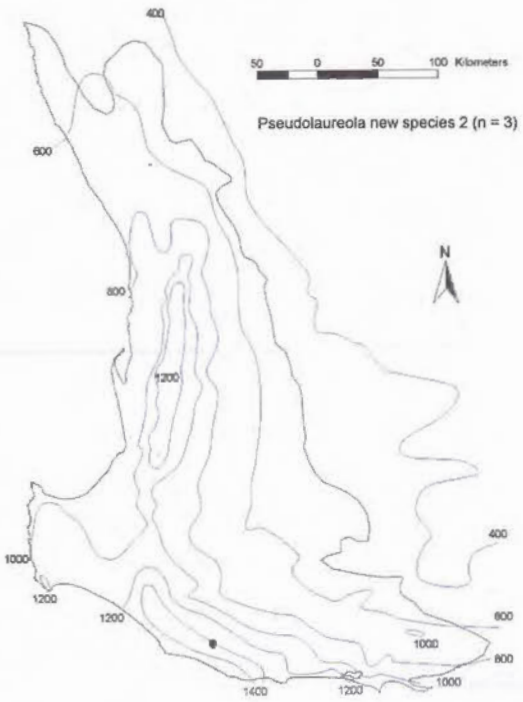
As well as these prominent local scale patterns, there were three notable restricted scale patterns within the central Warren (Figure 4.13). A new species of Notoniscus was found in the high rainfall karri forest in the Charnwood (Locality 88) and Pemberton (Locality 89) localities. The highly restricted Pseudolaureola new species 2 occurred at two adjacent sites midway between the two major populations of P. wilsmorei. Further east, the equally highly restricted Hanoniscus nichollsi was found in the far south coastal districts in the Walpole area (Locality 107). Although the distributions of these species are clear, microhabitat assumptions are drawn from much fewer records than the previous taxa and have been grouped. All species were generally found in litter and were found under karri bark. H. nichollsi was the only species collected from logs, a feature previously noted by Bowley (1935). The new species of Notoniscus was collected from leaf litter (by Berlese funnel, J. M. Waldock pers. comm., 2000) and from under karri bark (Appendix 2) at an extremely wet site in the karri forest (pers. obs.). What has become clear throughout all the high rainfall patterns in the south of the region is the importance of karri trees. Karri bark and the litter it produces are important microhabitats throughout the far south of the region. The presence of karri trees is an important determinant in species distribution at both the local and restricted scale. Throughout their range, karri trees hosted 28 of the 60 taxa whose distributions are illustrated here.

4.5.1. THE IMPORTANCE OF THE KARRI TREE

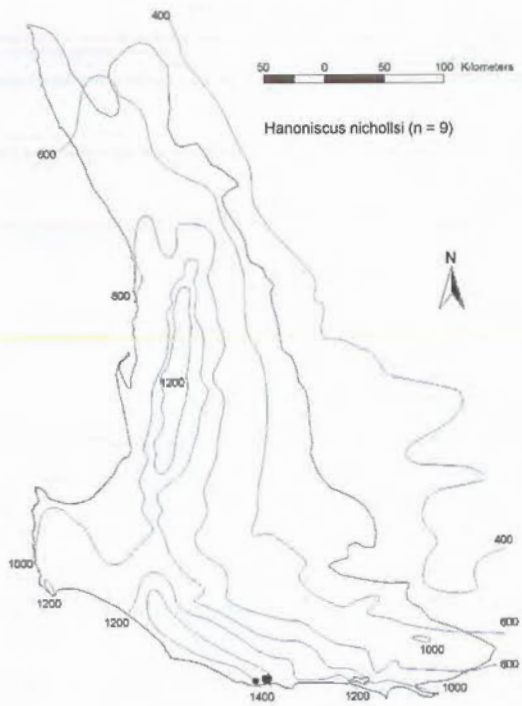
The properties of karri trees and the litter produced from the bark appear very important to the provision of microhabitat in wetter forest areas. The trunk of the tree itself and the accumulated bark at its base provide a moisture continuum. Invertebrates inhabiting the tree can potentially move up and down seasonally, from bark to litter, according to prevailing moisture conditions. The bark litter at the base of large trees is dense and deep and provides for year round moist conditions. The tree itself acts as a water harvesting mechanism, channelling water down the trunk and branches into the litter at the base. In other situations it has been shown that a considerable portion of the water falling on a canopy eventually reaches the soil in a relatively narrow band around the base of the tree (Voigt, 1960). Bark texture is also important in this process and the smooth bark of karri over most of the tree would enhance this process. Tree species with roughly textured bark have a greater capacity to absorb water (Voigt, 1960). The karri tree and its accumulated bark litter are illustrated in Plate 4.1 and 4.2.



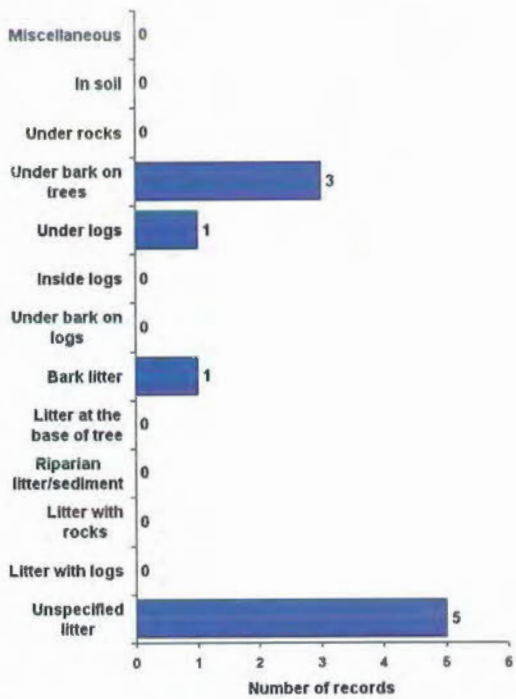
Restricted scale distribution of Notoniscus new species.



Restricted scale distribution of Pseudolaureola new species 2.



Restricted scale distribution of Hanoniscus nichollsi.



Combined total microhabitat utilisation for Notoniscus new species, Pseudolaureola new species 2 and Hanoniscus nichollsi.

Figure 4.13. The restricted scale distributions and combined microhabitat utilisation of Hanoniscus nichollsi, Notoniscus new species and Pseudolaureola new species 2 forming part of High Rainfall Patterns. Raw data for species microhabitat utilisation are tabulated in Appendix 2.

Plate 4.1. A karri (E. diversicolor) tree at Site 126 (See Appendix 1a for details) showing the build up of shed bark around the tree. Trees generally retain bark upon the trunk of the tree around their base.

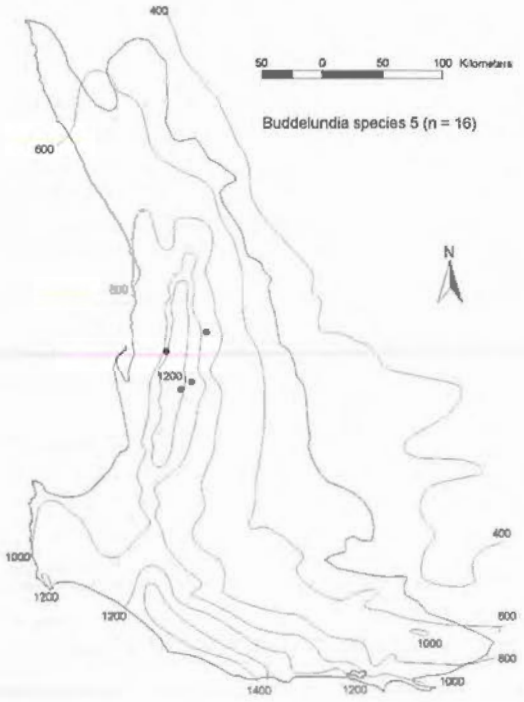
Plate 4.2. A karri (E. diversicolor) tree at site 130 (See Appendix 1a for details) showing bark removed from the tree and excavated bark litter at the base of the tree.

The refugial microhabitat properties of karri bark litter have been demonstrated by Giribet (2003) who described a new genus (Karripurcellia) of the Opilionid family Pettalidae from karri litter near Pemberton. The family Pettalidae is a good example of a Gondwanic invertebrate (Giribet, 2003). Other Australian genera of Pettalids are known only from Queensland rainforests. As well as the litter, the bark of the tree is also important. The composition of invertebrates can vary with the aspect of the tree (pers. obs.), with isopods being found usually upon the shady side (pers. obs.; see also Nicholls & Barnes 1926b and Subsection 3.2.2.). The refugial properties of the bark upon bark-shedding eucalypts were documented by Baehr (1990). He considered such trees to have unique subcortical carabid fauna. The low thermal conductivity of the bark is considered important because it means that bark could provide refuge during a fire which removed the ground litter. The uniqueness of trunk-dwelling communities upon Australian forest trees was illustrated by Proctor et al. (2002) who showed that oribatid mite communities occurring on tree trunks were almost 100% distinct from those occurring in the litter below them.

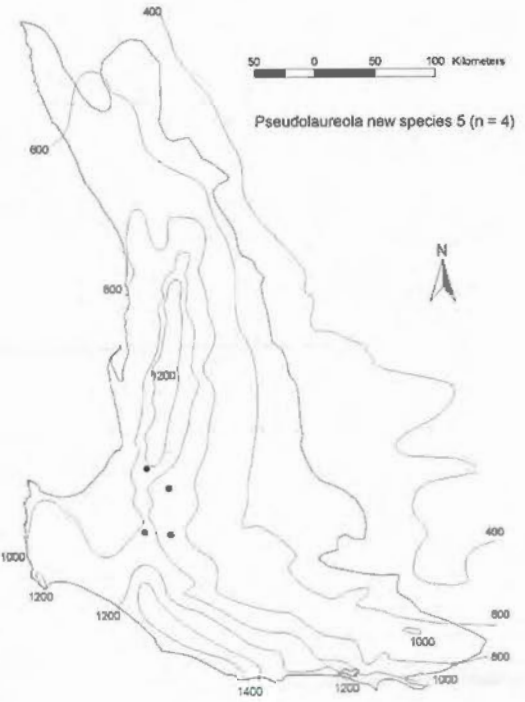
4.5.2. THE WET JARRAH FOREST

Three species, two locally distributed species, Buddelundia species 5 and Pseudolaureola new species 5, and the restricted Pseudolaureola new species 1, were found within high rainfall jarrah forest (Figure 4.14). Buddelundia species 5 was found at four sites to the north of the range of the sub-regional Buddelundia species 6. Pseudolaureola new species 1 was found at two sites to the south of Buddelundia species 5 and in close proximity to the northern outliers of Buddelundia species 6 (Figure 4.10). Buddelundia species 5 and Pseudolaureola new species 1 had very similar scale distributions. The slightly more localised Pseudolaureola new species 1 was found approximately midway between Pseudolaureola new species 5 and Buddelundia species 5, overlapping slightly with the latter. The three species were found almost exclusively in leaf litter; Buddelundia sp. 5 had a single record from and under bark and Pseudolaureola new species 5 had a single record from under logs. These three taxa further emphasise the importance of leaf litter as a microhabitat in the wetter jarrah forest.

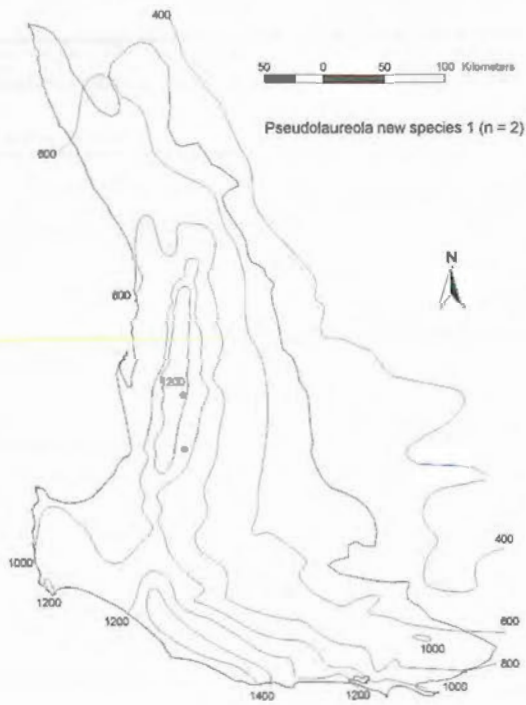
Figure 4.15 shows the distribution and microhabitat data of two species of Styloniscus. It further highlights some differences between Styloniscus and other high rainfall taxa. Styloniscus species 3 has a distribution similar to H. nichollsi except that it is also found further to the west in the Northcliffe (Locality 97) locality. In contrast tc Styloniscus species 7 (the most abundant species in the Warren), it is known only from leaf litter. The distribution of Styloniscus species 6 is formed by the disjunct occurrence at two sites. In contrast to other high rainfall jarrah forest taxa, it was found only in rotting logs. However, it is consistent with the microhabitat utilisation of Styloniscus species 1 in the jarrah forest and Styloniscus species 7 in the Warren. Its disjunct distribution probably represents the scarcity of this type of microhabitat throughout the jarrah forest. Both records for Styloniscus species 6 came from riparian zones.



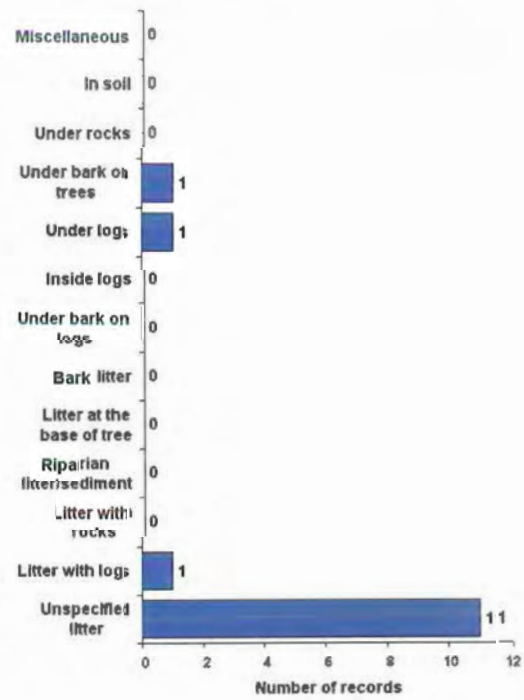
Local scale distribution of Buddelundia species 5.



Local scale distribution of Pseudolaureola new species 5.

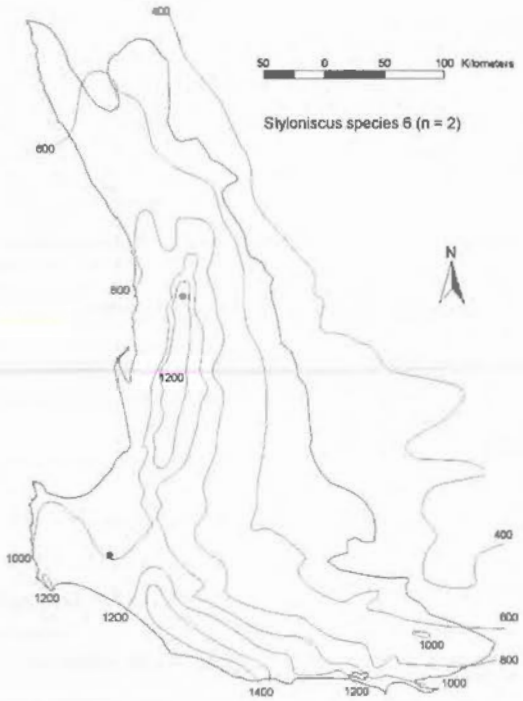


Restricted scale distribution of Pseudolaureola new species 1.

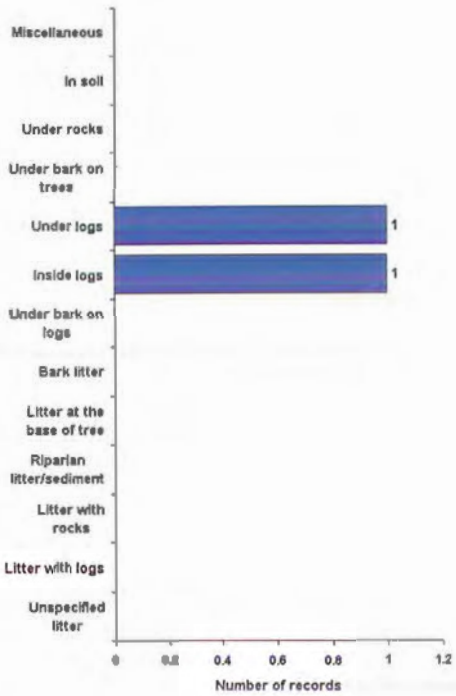


Combined total microhabitat utilisation for Buddelundia species 5, Pseudolaureola new species 5 and Pseudolaureola new species 1

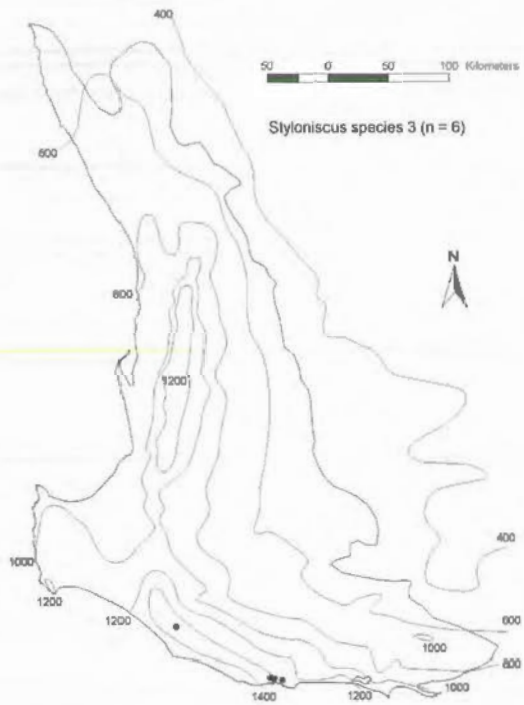
Figure 4.14. The local scale distributions of Buddelundia species 5 and Pseudolaureola new species 5, the restricted scale distribution of Pseudolaureola new species 1 and their combined microhabitat utilisation forming part of High Rainfall Patterns. Raw data for species microhabitat utilisation are tabulated in Appendix 2



Sub-regional scale distribution of Styloniscus species 6.



Total microhabitat utilisation for Styloniscus species 6.



Local scale distribution of Styloniscus species 3.

Total microhabitat utilisation for Styloniscus species 3.

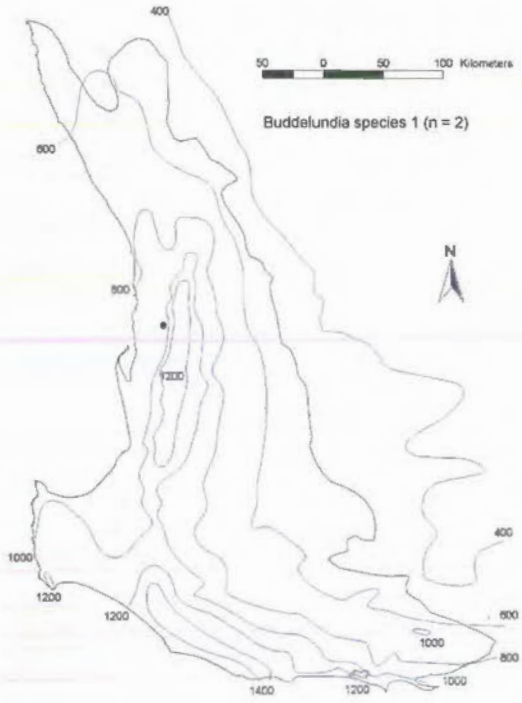
Figure 4.15. The sub-regional scale distribution of Styloniscus species 6, the local scale distribution of Styloniscus species 3 and the microhabitat utilisation of both species forming part of High Rainfall Patterns.

The underlying trend in high rainfall patterns is that smaller scale distributions result in more specialised microhabitat utilisation. This is generally a dependence on leaf litter but there are important exceptions. High rainfall taxa contribute significantly to the regional richness, particularly in the south of the region. Their contribution to regional beta diversity is important because high rainfall taxa often replace other forest taxa. At wetter sites in the Jarrah Forest, the presence of high rainfall taxa may only add one or two species to site richness but their presence is significant due to the fact that they are clearly related to more widely distributed taxa of the Warren. The presence of high rainfall taxa in the wetter parts of the Jarrah Forest Bioregion is dependent upon the presence of large and decaying logs and the build-up of leaf litter.

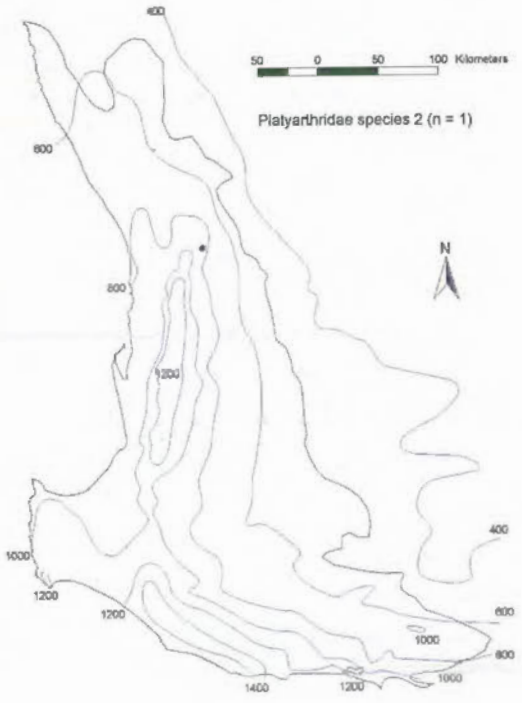
4.6. SINGLE LOCALITY PATTERNS

It is difficult to determine whether a taxon is genuinely found only at a single locality or if it is a representation of a restricted or local pattern undetectable due to the scale of sampling. However, when the single locality taxa are examined collectively they can contribute significantly to a regional biogeography. Six of the nine taxa included in this pattern occurred within, or close to the 1000 mm isohyet in the north of the region, while the other three occurred close to the 1000mm isohyet in the south east and south west of the region. It seems likely therefore, that most, if not all, these taxa are probably high rainfall taxa. In this case, they are best discussed after High Rainfall Patterns. The taxa detailed here provide further evidence of small-scale endemism in the wetter forested parts of the region.

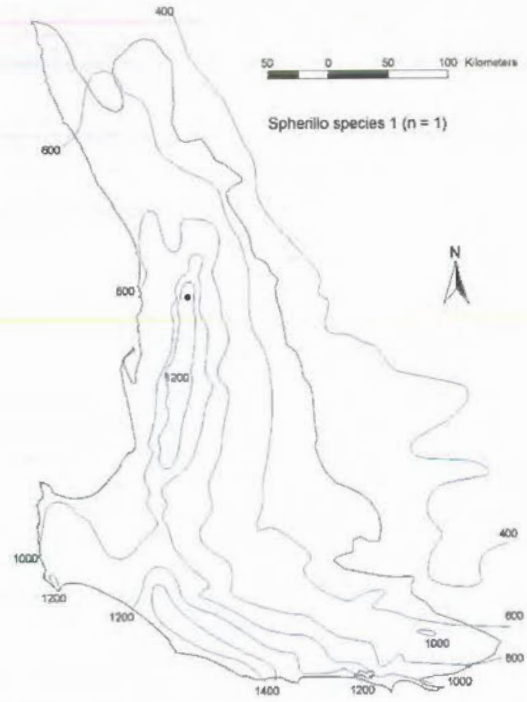
Figure 4.16 shows the distributions of four species, only one of which has microhabitat data. The first of these, Buddelundia species 1 has uncertain locality data. There are two records for the same locality both collected by L. Glauert in 1928. The locality data given on labels eccompanying the specimens is "Serpentine". Unfortunately, there are two localities called Serpentine in Western Australia. It is assumed that the specimens were collected from the region because all other material examined that was collected by Glauert was from south-western Australia. However, It should be stated that the specimen, by the nature of the dorsal surface, is quite different from all other Buddelundia described earlier. It also shares characters more typical of those found in arid localities rather than the high rainfall parts of the region. However, the locality of Serpentine has some unique geomorphological features that may give rise to some local adaptations of species. The distribution of this species is also consistent with other single locality taxa. The specimens examined had no microhabitat data and the species could have been collected in the locality of Wellard (Locality 29) or Jarrahdale (Locality 30). These localities are in the Swan Coastal Plain and Jarrah Forest respectively. The boundary of these bioregions is notably species rich, an issue that will be discussed later.



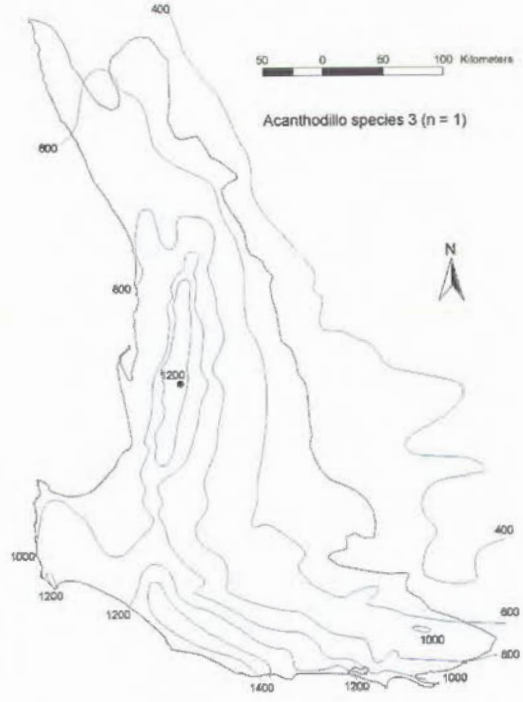
Single locality scale distribution of Buddelundia species 1.



Single locality scale distribution of Plathyarthridae species 2.



Single locality scale distribution of Spherillo species 1



Single locality scale distribution of Acanthodillo species 3.

Figure 4.16. The distributions of Buddelundia species 1, Platyarthridae species 2, Spherillo species 1 and Acanthodillo species 3 forming part of Single Locality Patterns.

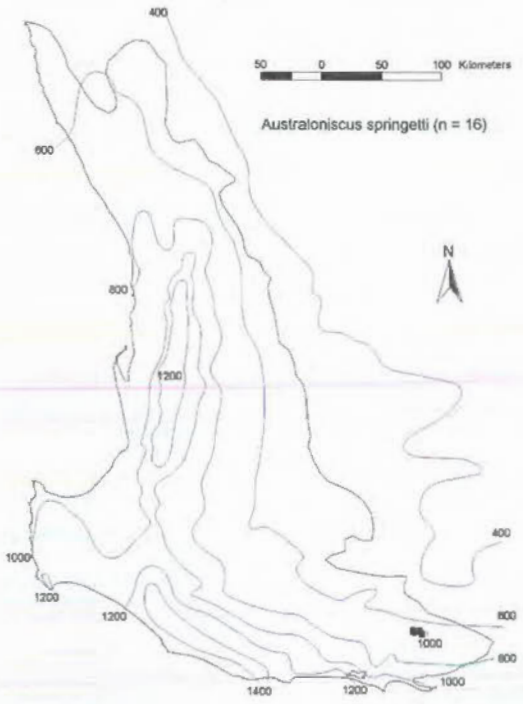
Platyarthridae species 2 is known from a single record, with no microhabitat data, collected in 1932. It appears to be material collected by either Nicholls or Bowley because the site, Wooroloo, coincides with other material collected by them at approximately the same time (see Bowley, 1935). The style of labelling and handwriting on the label accompanying the specimen is also characteristic of material examined by Bowley.

Spherillo species 1 was collected from under a log adjacent to the banks of the upper reaches of the Canning River (Site 32, Appendix 2) and it is worth noting that it came from the same log as Styloniscus species 6 discussed in the previous subsection. It provides further evidence of the few restricted log-dwelling taxa in the Jarrah Forest. Acanthodillo species 3 also found in high rainfall jarrah forest is found within the range of Buddelundia species 5 and Pseudolaureola new species 1. Both Spherillo species 1 and Acanthodillo species 3 have very precise locality data.

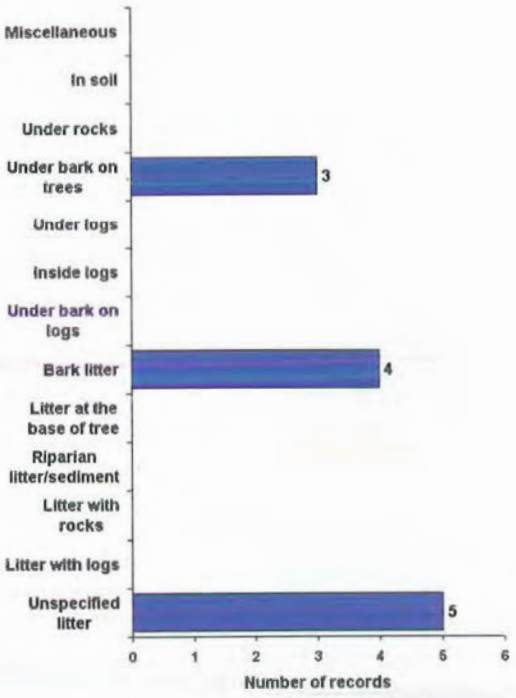
Figure 4.17 illustrates further leaf litter dependence in higher rainfall jarrah forest. Three species with markedly different distributions were all found in leaf litter. Pseudodiploexochus species 3 was extracted from leaf litter by Berlese funnel and was found in the same locality as Acanthodillo species 3. Two similar species of Styloniscus, Styloniscus species 4 and Styloniscus species 5 were found in leaf litter at contrasting and disparate localities. Styloniscus species 5 occurred in the north of the region in the Jumperkine (Locality 19) locality, an area of intermediate rainfall in the Darling Scarp where exposed granite with deep fissures are commonplace. The potential cryptic nature of this species and patchy distribution of this type of geological formation may explain its restricted distribution. Styloniscus species 4 was obtained from leaf litter by Berlese Funnel extraction from a long unburnt remnant of jarrah/marri woodland on private property in the Yallingup (Locality 57) locality. The presence of this species may be due to a combination of accumulated litter due to a long absence of fire and intensive sampling of leaf litter carried out at this site.

Figure 4.18 illustrates the distribution of two species found in the south east of the region. Australoniscus springetti was found only at the Porongurup Range, in the locality of Porongurup (Locality 104), an outlying distribution of karri and a prominent geological feature. It appears to be both abundant (pers. obs.) and mobile since it was represented in pitfall traps (Appendix 2), leaf litter, karri bark litter and under karri bark. Its presence at this locality is not surprising since the Porongurup Range is a unique geological feature in the region and consists of large granite peaks surrounded by tall trees. This environment is conducive to the accumulation of moisture and organic matter, and protected from fire by surrounding farmland[12]. The Range is also an outlier of the high rainfall in an area of moderate to low rainfall.

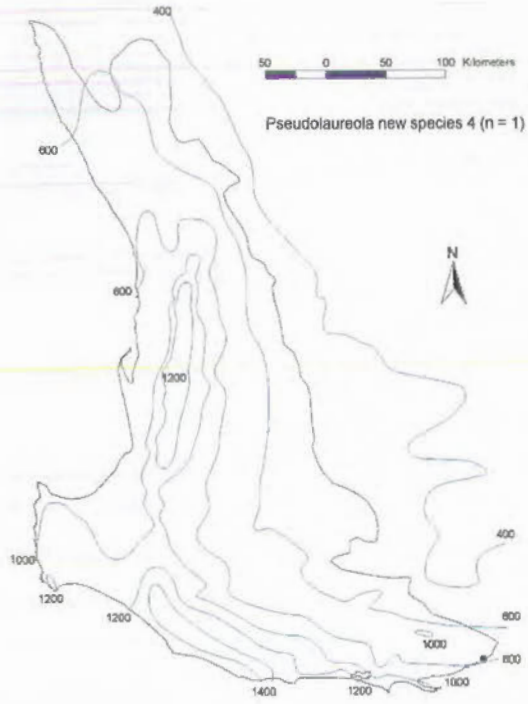
[12] But not from the effects of farming and the activities of farmers.



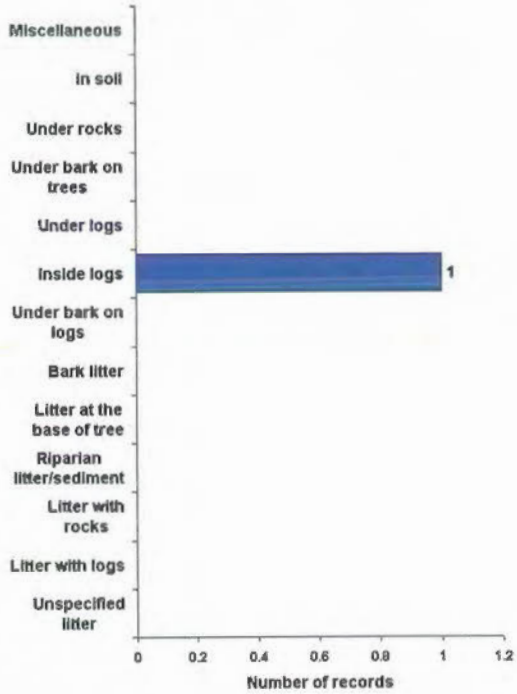
Single locality scale distribution of Australoniscus springetti.



Total microhabitat utilisation for Australoniscus springetti.

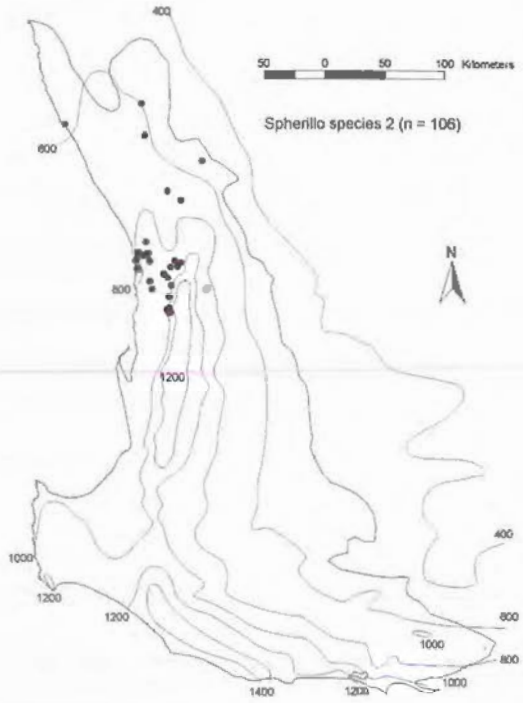


Single locality scale distribution Pseudolaureola new species 4.

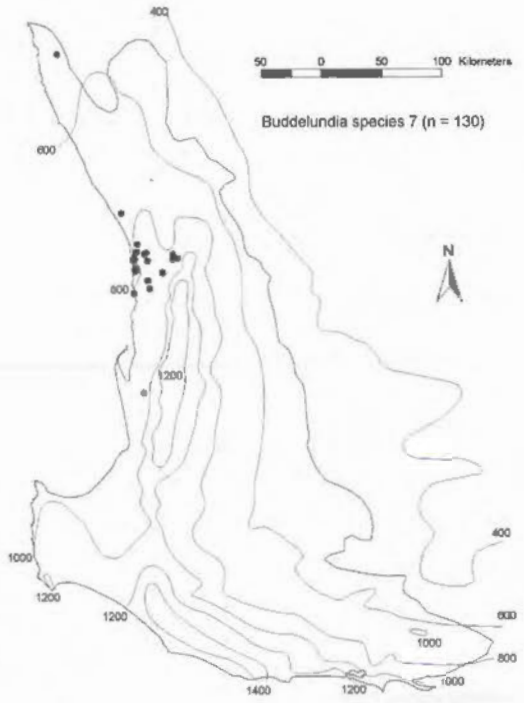


Total microhabitat utilisation for Pseudolaureola new species 4.

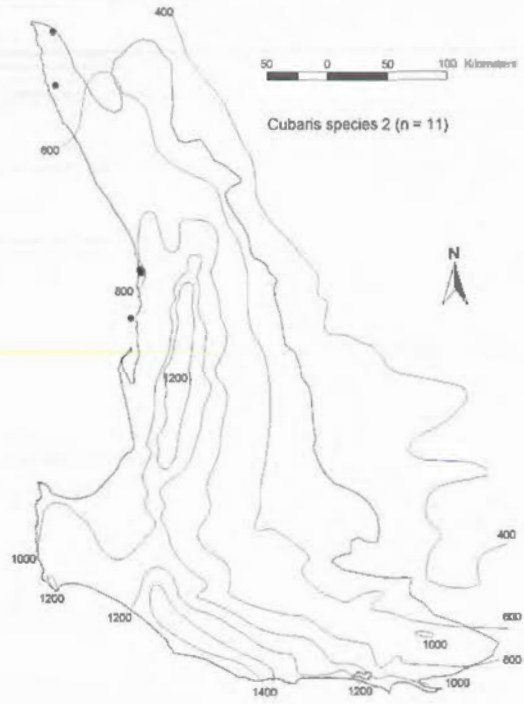
Figure 4.18. The distributions of Australoniscus springetti and Pseudolaureola new species 4 and their microhabitat utilisation forming part of Single Locality Patterns.



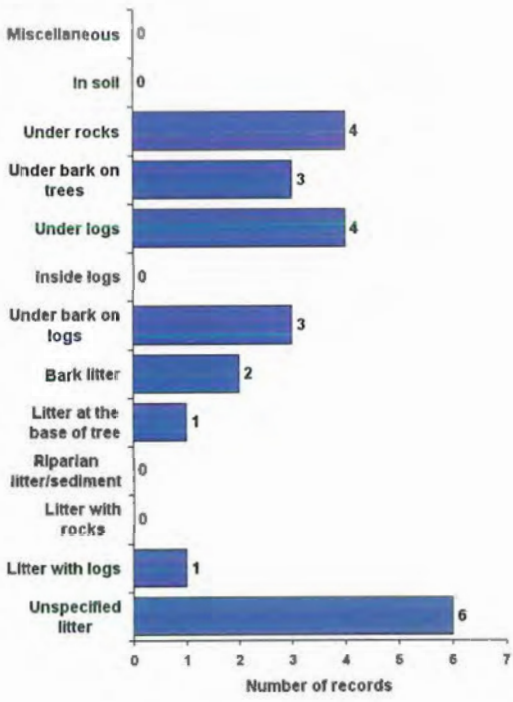
Sub-regional scale distribution of Spherillo species 2.



Local scale distribution of Buddelundia species 7.



Local scale distribution of Cubaris species 2.



Combined total microhabitat utilisation for Spherillo species 2, Buddelundia species 7 and Cubaris species 2.

Figure 4.19. The sub regional scale distribution of Spherillo species 2, the local scale distributions of Buddelundia species 7 and Cubaris species 2 and their combined microhabitat utilisation forming part of Northern Patterns. Raw data for species microhabitat utilisation are tabulated in Appendix 2.

Pseudolaureola new species 4 was found at the most easterly site (Site 122) sampled during this study (Figure 4.18). In contrast to other locally distributed and restricted Pseudolaureola, this species inhabited a rotting log, illustrate by Plate 4.3. It was found in a wooded valley in part of the Waychinicup National Park in locality of Manypeaks (Locality 114). The relative rarity of wooded localities in this most easterly of localities and the highly localised distributions of many of the Pseudolaureola detailed here, suggest that this species has potentially a very limited distribution.

Plate 4.3. The microhabitat of Pseudolaureola species 4. A very damp and well-rotted log. A rare microhabitat to encounter in this, or any, part of the Jarrah Forest Bioregion. Photo: L. Manal.

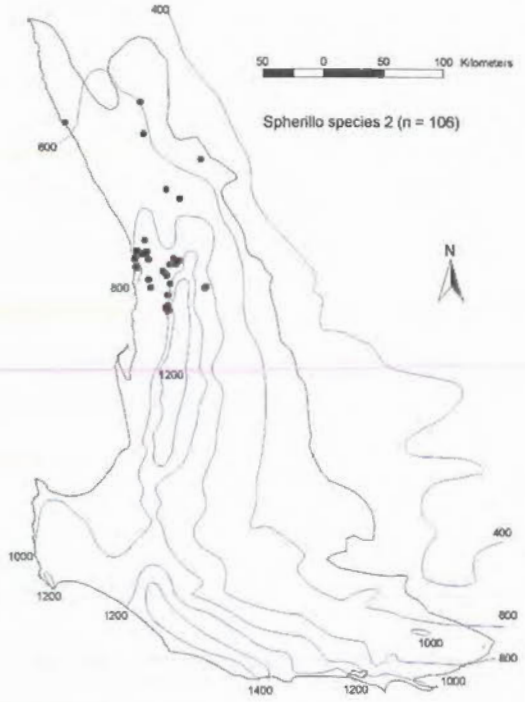
Single locality taxa display microhabitat characteristics of litter-dependent wet forest taxa, taxa whose distributions correspond with prominent physical features of the landscape and cryptic taxa. As stated, some of the taxa could easily have been included in high rainfall patterns but their presence was also probably influenced by physical features or site characteristics such as forest integrity or time since fire. It is interesting to note that none of the single locality taxa were found in the Warren Bioregion. With the exception of A. springetti and Platyarthridae species 2, all were in the wettest part of the jarrah forest. Single locality taxa contribute significantly to the site richness in wetter parts of the jarrah forest making them extremely important sites of regional endemism.

4.7. NORTHERN PATTERNS

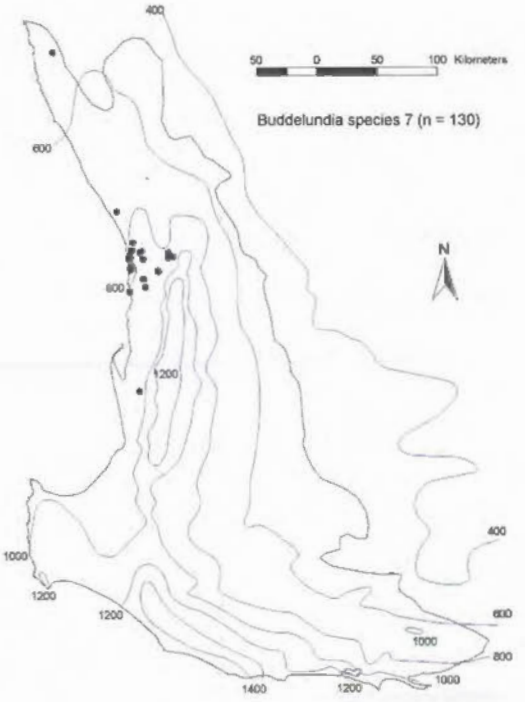
Patterns from the northern Swan Coastal Plain and the northern Jarrah Forest Bioregions differed markedly from those of the more southerly forests, and were the clearest of any in the region. This may be due to the number of records present and is certainly a partial representation of the amount of material collected as a result of an intensive pitfall trapping survey of remnant urban bushland (hereafter termed UBC) in the Perth (Locality 21) and adjacent localities in the mid 1990s (see How et al., 1996 & Harvey et al., 1997). Distributions were unique in the sense that all but one of the 12 taxa were locally distributed. With a few exceptions, taxa showed a high degree of bioregional specificity and were much less dependent on leaf litter than those described in the preceding sections.

Figure 4.19 shows the distribution of three species of Armadillidae that are confined largely to the north of the Swan Coastal Plain. The sub-regionally distributed Spherillo species 2 and the locally distributed Buddelundia species 7 were widely found on the Swan Coastal Plain and on the western fringe of the Jarrah Forest. Records for these species were dominated by pitfall trap occurrences (Appendix 2) from the Perth locality (Locality 21) implying a high degree of epigean mobility. The relatively few records with microhabitat data indicate that both species also have a wide range of microhabitat utilisation. The distribution of Cubaris species 2 differs from the other two in that it occurs only coastally, in association with tuart (E. gomphocephala) woodland that grows in parts of the Spearwood dune system where limestone outcropping occurs. It was collected from leaf litter in association with logs, under logs, under the bark on logs, and under rocks (Appendix 2).

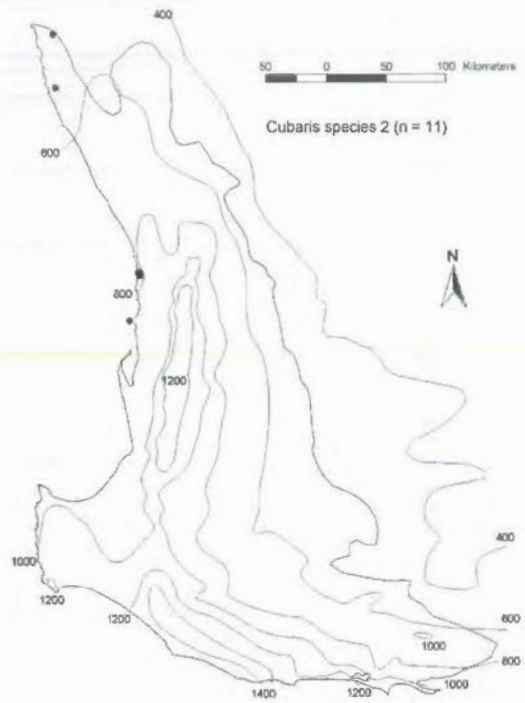
In contrast to Figure 4.19, Figure 4.20 shows three locally distributed taxa occurring largely in the northern part of the Jarrah Forest Bioregion. Buddelundia species 4 occurred at similar latitude to Buddelundia species 7 and the distributions of the two species overlapped on the eastern fringe of the Swan Coastal Plain in the Perth locality (Locality 21). The majority of records for Buddelundia species 4 were also from pitfall traps (Appendix 2) in the eastern part of the Perth locality. However, at sites in the northern Jarrah Forest, where most of the microhabitat data came from, the species showed a wide range of microhabitat utilisation and less association with leaf litter (Appendix 2, 43.8%) than the mainly coastal Buddelundia sp. 7 (Appendix 2, 60%).



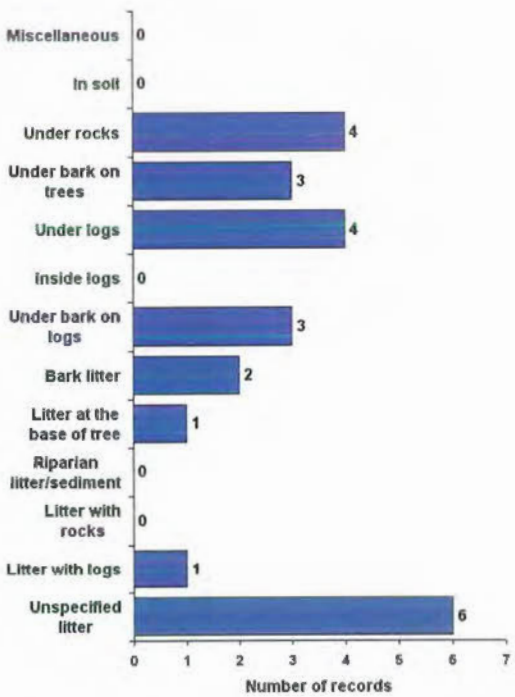
Sub-regional scale distribution of Spherillo species 2.



Local scale distribution of Buddelundia species 7.

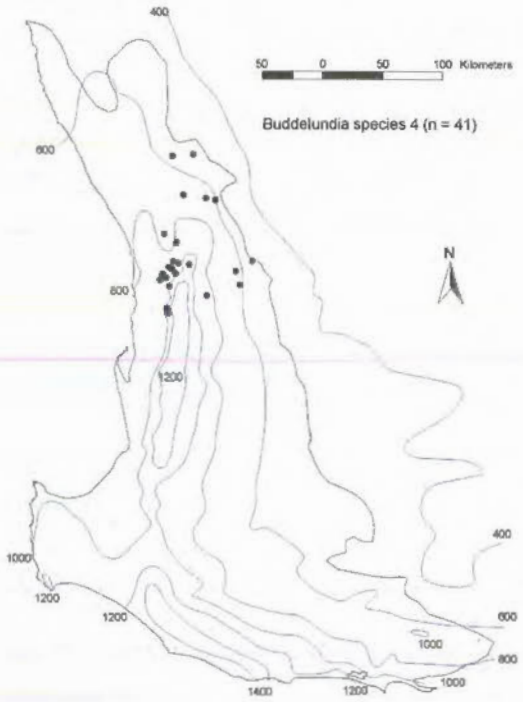


Local scale distribution of Cubaris species 2.

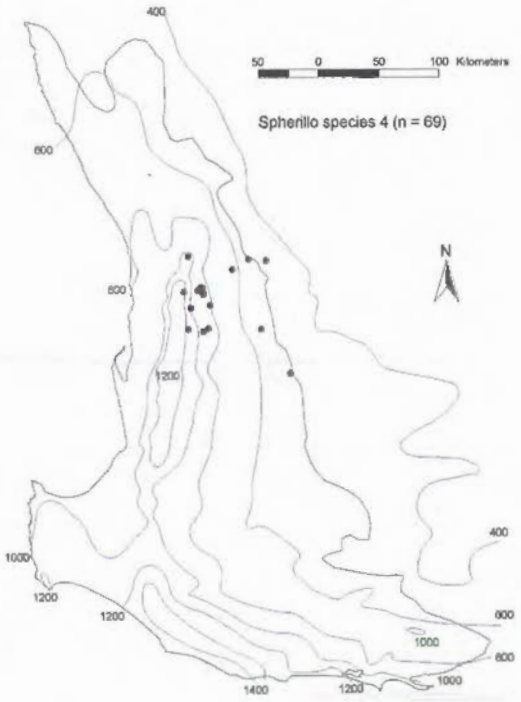


Combined total microhabitat utilisation for Spherillo species 2, Buddelundia species 7 and Cubaris species 2.

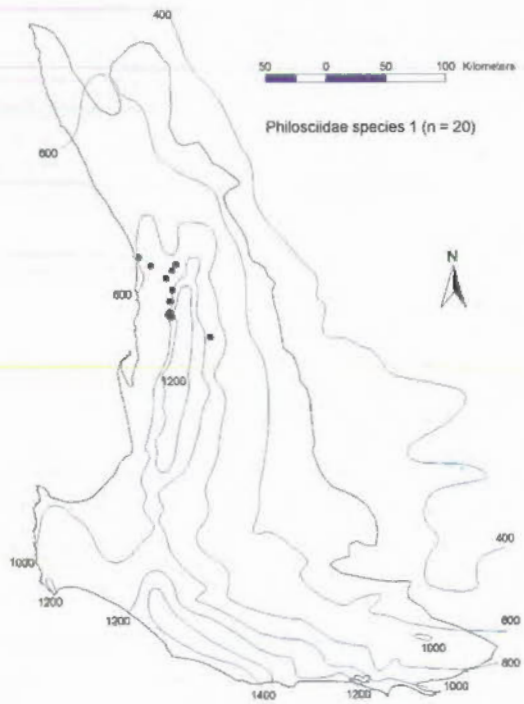
Figure 4.19. The sub regional scale distribution of Spherillo species 2, the local scale distributions of Buddelundia species 7 and Cubaris species 2 and their combined microhabitat utilisation forming part of Northern Patterns. Raw data for species microhabitat utilisation are tabulated in Appendix 2.



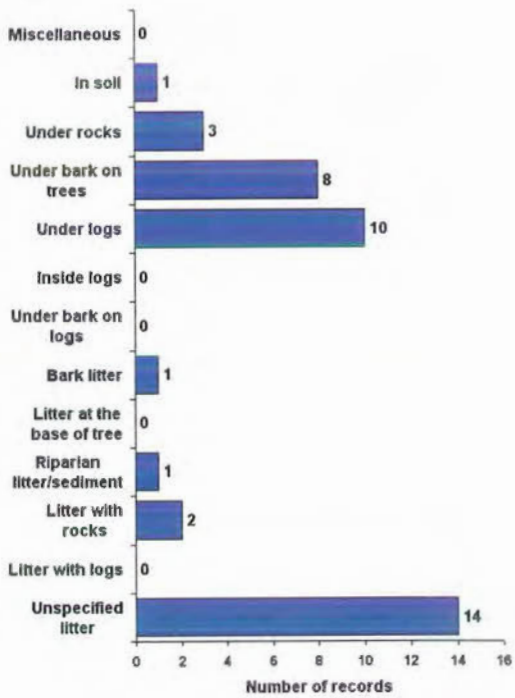
Local scale distribution of Buddelundia species 4.



Local scale distribution of Spherillo species 4.



Local scale distribution of Philosciidae species 1.



Combined total microhabitat utilisation for Buddelundia species 4, Spherillo species 4 and Philosciidae species 1

Figure 4.20. The local scale distributions of Buddelundia species 4, Spherillo species 4 and Philosciidae species 1 and their combined microhabitat utilisation forming part of Northern Patterns. Raw data for species microhabitat utilisation are tabulated in Appendix 2

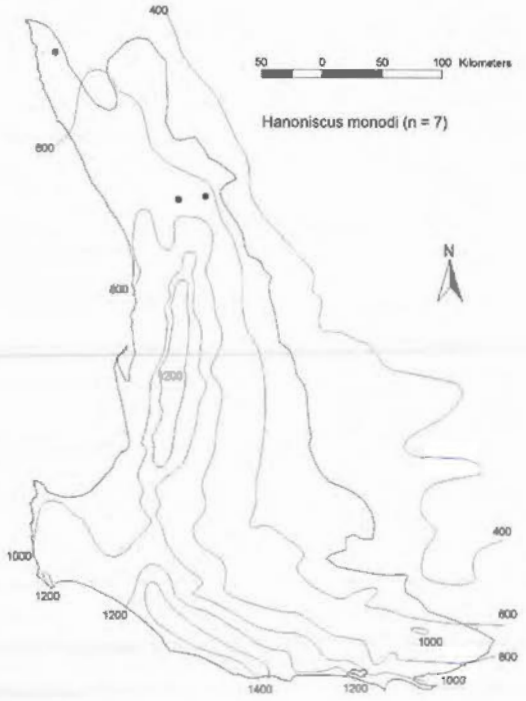
Spherillo species 4 was found only in the northern Jarrah Forest but was notably absent from jarrah remnants in the northern part of the Jarrah Forest Bioregion. However, it extended well into the drier eastern margins, around the 600 mm annual isohyet of the Jarrah Forest where wandoo woodlands dominate. This species is similar to Spherillo sp. 5 discussed in forest patterns. The distributions of the two species overlap slightly and both Spherillo species 4 and 5 occupy a wide range of microhabitats. Unlike Spherillo species 5, Spherillo species 4 was substantially represented in pitfall traps (Appendix 2). However, this is a result of a single, small scale and intensive study of jarrah forest at Mount Dale in the locality of Beraking (Locality 27) (A. Watson, pers. comm., 2001).

Philosciidae species 1 had a similar, although less widespread, distribution to Spherillo species 2 and Buddelundia species 7 but was also less confined to the Jarrah Forest. It was also collected almost exclusively from pitfall traps (Appendix 2, 80%). The only record with microhabitat data were from leaf litter and, whilst consistent with the regionally distributed Laevophiloscia species 2, it is in contrast to other northern pattern taxa. The species appears more restricted on the Swan Coastal Plain, occupying sites at the foot of the Darling Scarp and some sites with tuart woodland remnants. The distribution of this species extended further into the jarrah forest than either Spherillo species 2 or Buddelundia species 7 because of outlying occurrences in pitfall traps at Mount Cooke in the Yaganing (Locality 31) locality.

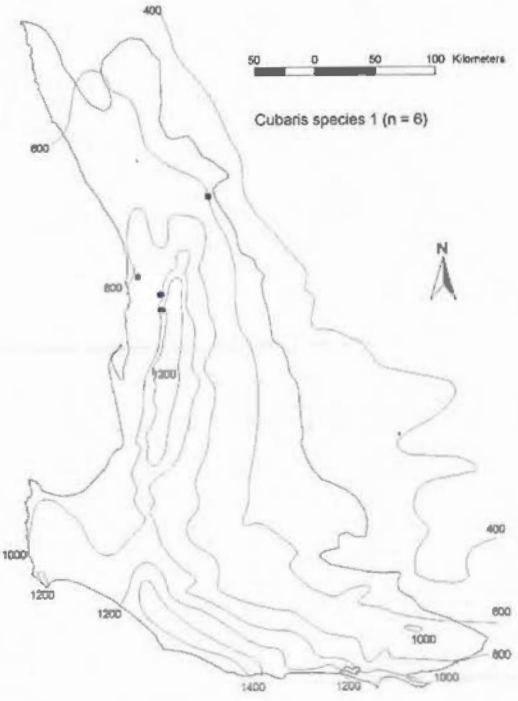
Figure 4.21 shows three species confined to the north of the region but less frequently encountered. This may be due to their association with particular landscape features and/or cryptic microhabitat utilisation. The number of records for each is limited and therefore interpretation of the patterns is less clear. However, the individual records for each of the species are revealing in themselves.

Hanoniscus monodi was collected from under tree bark in a riparian situation (Appendix 2) and from under a log next to a drying creek bed (Appendix 2, pers. obs.). These observations concur with those of Bowley (1935) who characterised H. tuberculatus, and to a lesser extent H. monodi, as swamp dwellers.

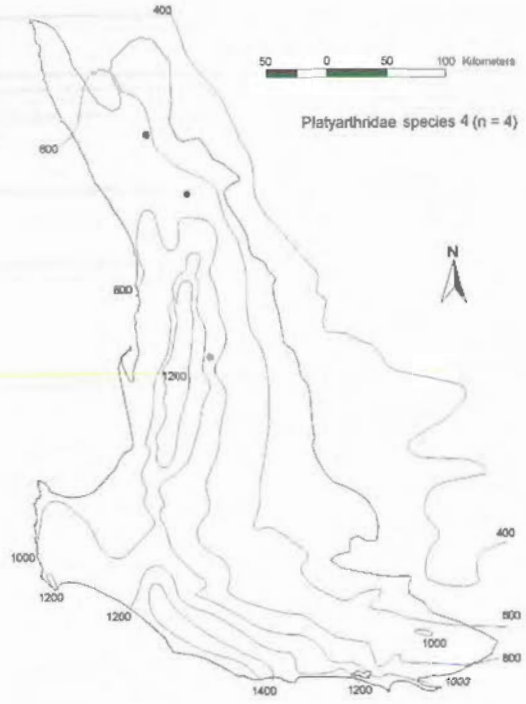
Platyarthridae species 4 was collected at three different localities. The species is long and thin and has pale colouring. This suggests an endogean habitat, which may explain its infrequent collection. Two records were obtained from the same site (Site 36) where it occurred both in litter and inside a log. It was also found under stones (Appendix 2).



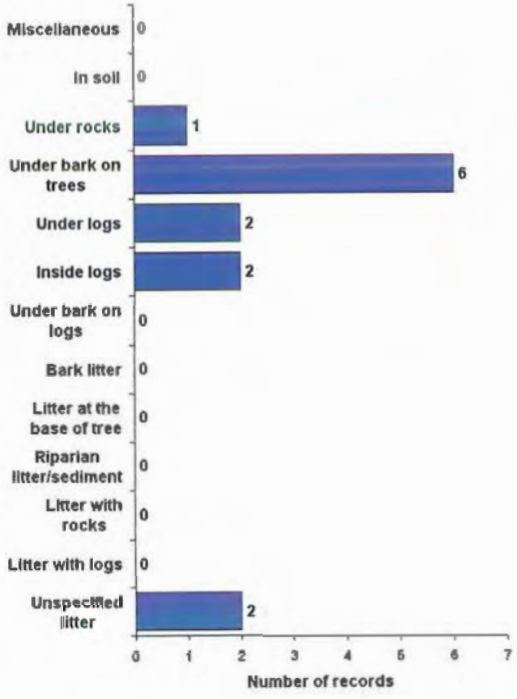
Local scale distribution of Hanoniscus monodi.



Local scale distribution of Cubaris species 1.



Local scale distribution of Platyarthridae species 4.



Combined total microhabitat utilisation for Hanoniscus monodi, Cubaris species 1 and Platyarthridae species 4

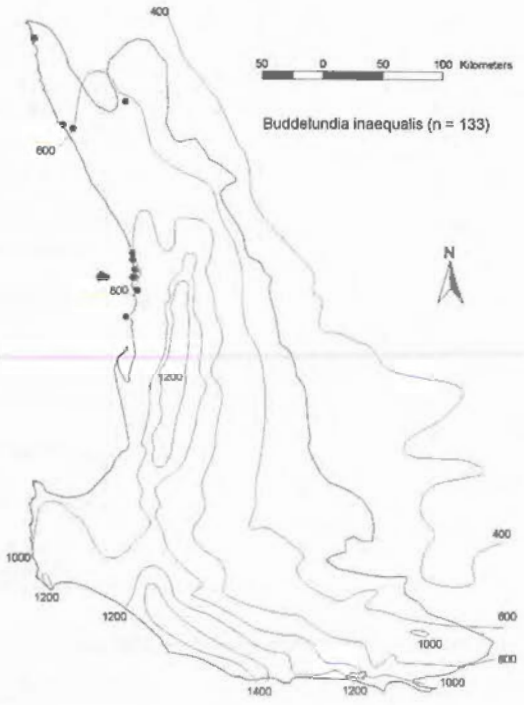
Figure 4.21. The local scale distributions of Hanoniscus monodi, Cubaris species 1 and Platyarthridae species 4 and their combined microhabitat utilisation forming part of Northern Patterns. Raw data for species microhabitat utilisation are tabulated in Appendix 2.

Six specimens of Cubaris species 1 occurred in three localities (Figure 4.21). Two of these are old specimens from Applecross and Armadale (collected 1934) and two are from pitfall traps (Appendix 2) at Norman Road Reserve at Cardup as part of the UBC. Harvey et al. (1997) pointed out that this reserve is in remarkably good condition and is close to the base of the Darling Scarp with characteristic clay soils. It is notable as it is one of the best surviving remnant populations of the grasstree genus Kingia on the Swan Coastal Plain. It is probable that Cubaris species 1 occurs in damp localities because both Applecross and Armadale would have had low-lying and damp localities, similar to those at Cardup. The remaining specimen was collected from in, and under, logs (Table 4.8) at a low-lying site (Site 41) dominated by wandoo in the locality of Dewars Pool (Locality 16). This specimen may in fact be a different species since ornamentation of the dorsal surface differs from those collected elsewhere. However, a confident diagnosis is not possible from a single specimen.

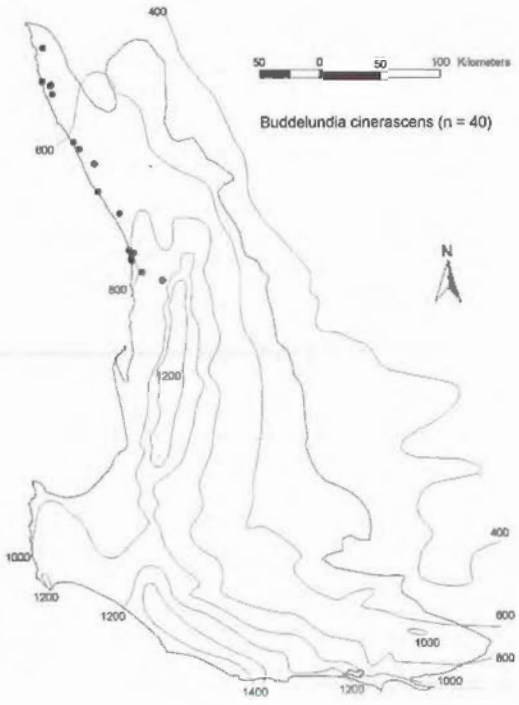
Figure 4.22 emphasises the longitudinal zonation already shown in Cubaris species 2 and Platyarthridae species 4. Longitudinal zonation is also evident in the Eastern Patterns described in the following section. Figure 4.22 shows the distributions of three species of Buddelundia, B. inaequalis, B. cinerascens and B. opaca. These species share a number of characters of the frontal ridge and first pereonite and, along with B. nitidissima, were the largest of the Armadillidae to occur in the region. While relatively large size (> 10 mm) may limit the use of some cryptic microhabitats, Buddelundia are widespread, mainly xeric species and were found to be much more common and diverse in the drier northern parts of the region.

B. inaequalis occurred in the immediate vicinity of the coast in association with limestone where it was equally common under rocks and to a lesser extent in leaf litter. There were no records from pitfall traps for this species (Appendix 2). The most easterly of the records is an old record (1925) with vague locality data and is therefore unreliable. It is shown as an outlier on the first map of Figure 4.22.

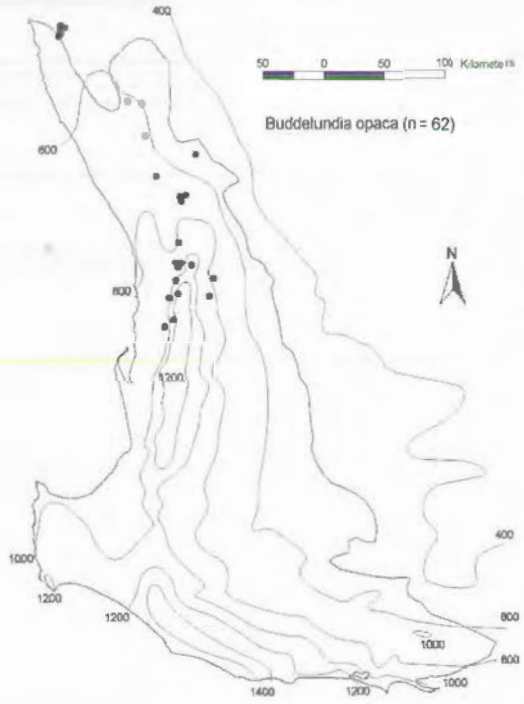
B. cinerascens also occurred coastally, but in the Spearwood sand dune systems that parallel coastal limestone features, and,like B. inaequalis, it was found in leaf litter and under rocks. Unlike B. inaequalis, it was found in pitfall traps and was common in some of the coastal bushland remnants of the northern Swan Coastal Plain. Its greater mobility and range is suggested by the fact that it was also quite commonly found under logs, under bark on logs and in soil. B. inaequalis and B. cinerascens both occur in the loose sandy soils of the Swan Coastal Plain and had high representation in soil. B. cinerascens co-occurred with Buddelundia sp. 7 at some sites in the Perth locality (Locality 21). The distribution of B. cinerascens is very similar to that of Cubaris species 2 although it was much more frequently collected.



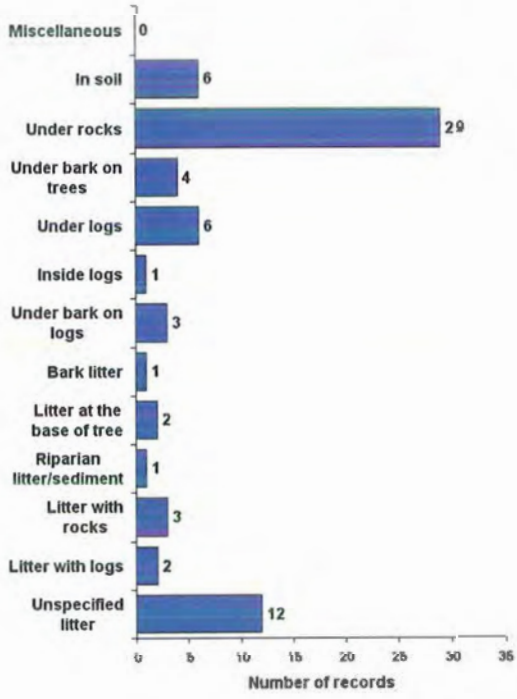
Local scale distribution of B. inaequalis.



Local scale distribution of B. cinerascens.



Local scale distribution of B. opaca.



Combined total microhabitat utilisation for B. inaequalis, B. cinerascens and B. opaca

Figure 4.22. The local scale distributions of Buddelundia inaequalis and Buddelundia cinerascens, the sub-regional scale distribution of Buddelundia opaca and their combined microhabitat utilisation forming part of Northern Patterns. Raw data for species microhabitat utilisation are tabulated in Appendix 2.

B. opaca is restricted to rocky biotypes in the jarrah forest, and a few sites on the north-western Swan Coastal Plain, and continues the pattern of longitudinal zonation. Not surprisingly, nearly half the records (Appendix 2) come from under rocks, the most for any taxon. A significant outlying population occurred in the north of the region in the locality of Lesueur (Locality 202). This locality contains a prominent rocky biotype and is a significant northerly outlier of the distribution of jarrah trees (Dell & Havel, 1987). B. cinerascens was the only one of the three species contributing to the pattern of longitudinal zonation not found exclusively in rocky biotypes and the only one collected from pitfall traps.

The distributions and microhabitat data in Figures 4.19-22 suggest that the northern and more seasonally dry parts of the region's geomorphological characteristics of the landscape contribute significantly to the provision of microhabitat. Whilst organic matter is important in its own right in wetter forest areas, in northern patterns it appears that the relationship between organic matter and physical properties of the landscape are critical. Table 4.3 shows that in northern patterns leaf litter accounted for only 35% of microhabitat utilisation whereas the average over all patterns was 53%. Microhabitat utilisation was similar to that for Eastern Patterns, which, to some extent, extend the longitudinal zonation shown by some northern pattern taxa.

The overlapping distribution of bioregional specific taxa in the Perth (Locality 21) and Fremantle (Locality 25) localities, combined with the facts that these localities contain most of the forest taxa, northern coastal taxa and taxa associated with Darling Scarp and some with damp areas, make them the richest in the region. This will be explored more fully in Chapter 5 and Chapter 8. The contribution of many local scale patterns dictates that endemism in the north of the region is largely at the local scale. This is similar to parts of the Warren, which is nearly as rich, and contrasts with the wetter parts of the Jarrah Forest where endemism occurs at much smaller scales.

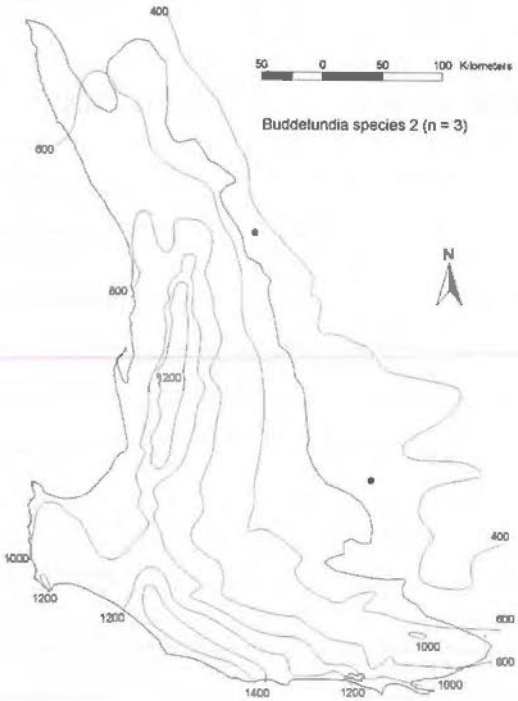
4.8. EASTERN PATTERNS

Four taxa occurred only in the eastern part of the region, largely on the eastern fringe of the Jarrah Forest close to or east of the 600 mm isohyet. These species are all locally distributed and are known from between 2 and 5 records. With the exception of Buddelundia species 2, which is known only from WAM material collected in 1929 and an unspecified date, all records have microhabitat data. In common with some locally distributed forest taxa, occurrence in the eastern and lower rainfall part of the region is characterised by use of logs and stones, and, a probable partial endogean existence. As a whole, these taxa were the least dependent upon leaf litter (Table 4.3). Due to the cryptic nature of these species, it is likely that they were infrequently collected. However, sufficient records are present here to give an indication of the overall consistency of the patterns. Further records may result in some of these patterns becoming sub-regional rather than local.

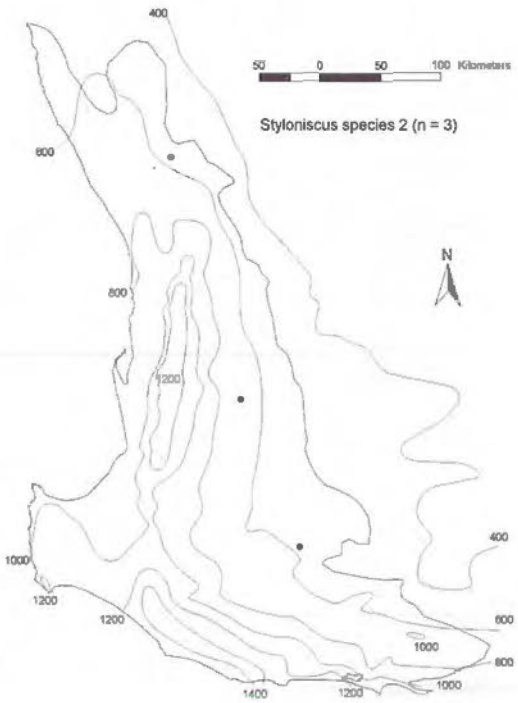
The presence of these species increases significantly the richness of eastern localities, since regionally distributed taxa are often the only of the taxa found here. Where there are significant remnants of forest vegetation in these localities, outliers of forest taxa are occasionally found. Figure 4.23 shows the distributions of three species from the east of the region, none of which occurred in leaf litter. Styloniscus species 2, the smallest of all the Styloniscus species was collected from three localities, each from a different microhabitat. The most northerly specimen was collected from under rocks, the central specimen from under a log, and the most southerly specimen from litter at the base of a wandoo tree, which characterise eastern parts of the region. Acanthodillo species 2 occurred at much the same longitude as Styloniscus species 2 and was collected from under logs and under stones.

Buddelundia species 2 occurred much further inland than the previous two species and, in fact, occurred just outside the region as it has been defined here. No specimens were collected from sites within the region. During the final part of the preparation of this chapter, some specimens, collected by the Western Australian Department of Conservation and Land Management from the Avon Wheatbelt Bioregion (to the east of the study area, see Figure 1.4), were examined. Some of these were Buddelundia species 2 and some a new species of Buddelundia. The material was from both woodland and salt lake environments. Therefore, the distribution of Buddelundia species 2, given in Figure 4.23, represents the western margin of a more comprehensive inland distribution.

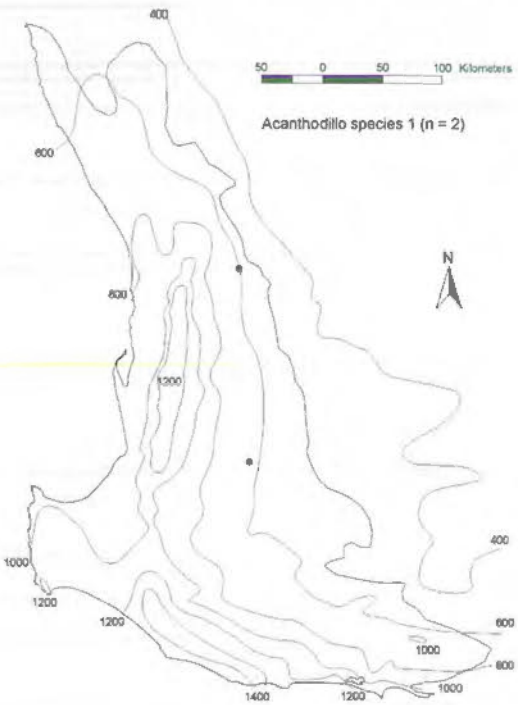
Figure 4.24 shows the distribution and microhabitat utilisation of Buddelundia albomaculata. It was more widely distributed than other species from the east of the region, but, was still considered to be at the local scale. The species is similar to B. nitidissima, which was also found in eastern localities, but is considerably smaller. The wider eastern distribution of this species may be explained by the fact that it was collected from a wide range of microhabitats. The five records are distributed evenly between microhabitats. The distribution given here encompasses the type locality, Broome Hill, shown on Figure 3.1.



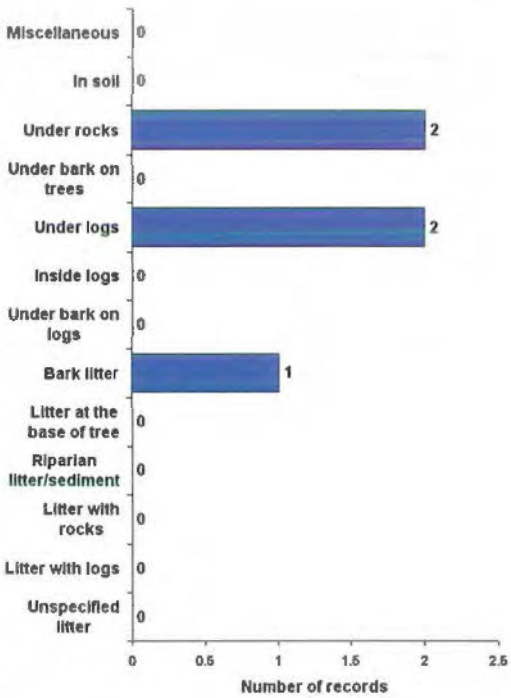
Local scale distribution of Buddelundia species 2.



Local scale distribution of Styloniscus species 2.

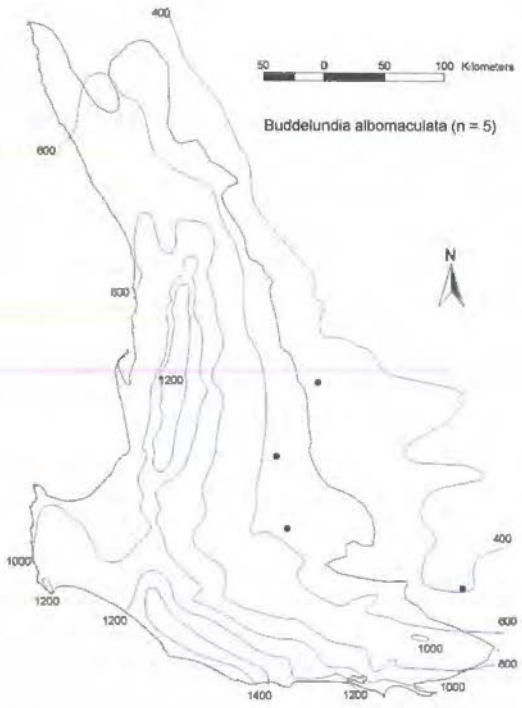


Local scale distribution of Acanthodillo species 1.

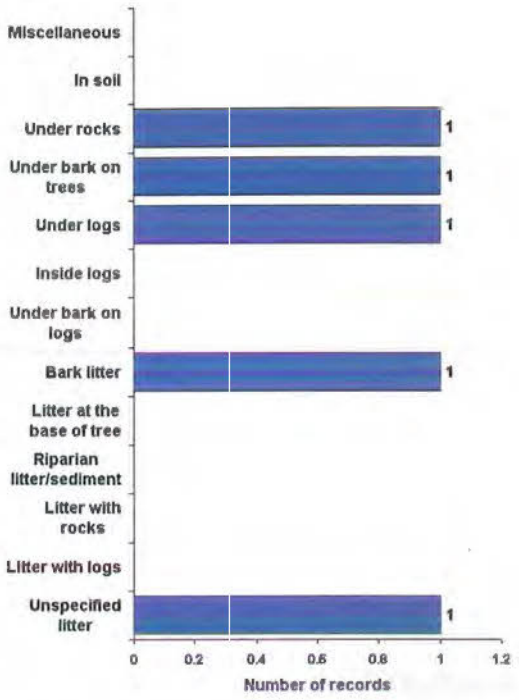


Combined total microhabitat utilisation for Buddelundia species 2, Styloniscus species 2 and Acanthodillo species 1

Figure 4.23. The local scale distributions of Buddelundia species 2, Styloniscus species 2 and Acanthodillo species 1 and their combined microhabitat utilisation forming part of Eastern Patterns. Raw data for species microhabitat utilisation are tabulated in Appendix 2.



Local scale distribution of Buddelundia albomaculata.



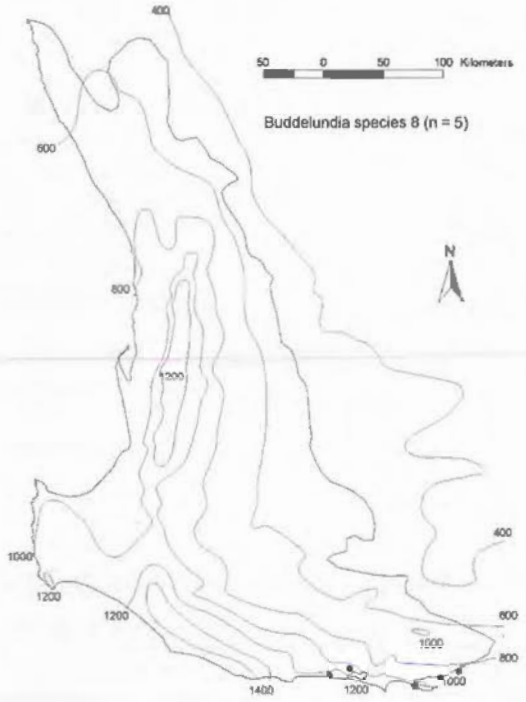
Total microhabitat utilisation for Buddelundia albomaculata

Figure 4.24. The local scale distribution and microhabitat utilisation of Buddelundia albomaculata forming part of Eastern Patterns. Raw data for species microhabitat utilisation are tabulated in Appendix 2.

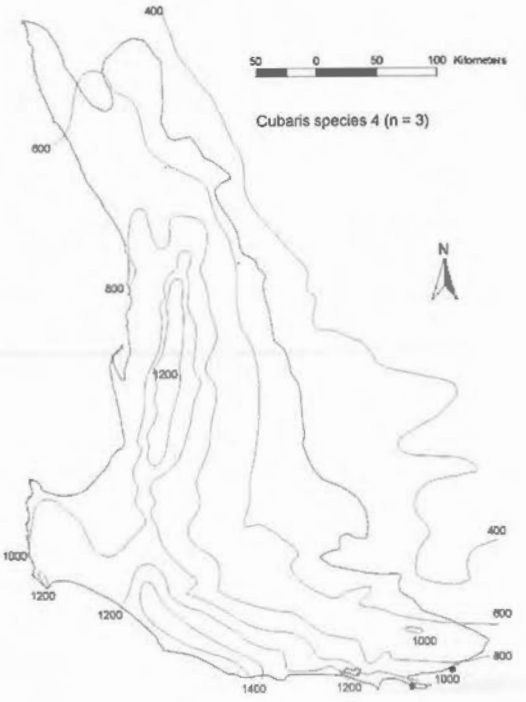
4.9. SOUTH EASTERN PATTERNS

As well as Pseudolaureola new species 4 and A. springetti discussed in single locality patterns, three taxa occurred only in the far southeast of the region. Figure 4.25 shows the locally distributed Buddelundia species 8 and the restricted Acanthodillo species 4 and Cubaris species 4. These species all occurred in the immediate vicinity of the coast in the far south of the Jarrah Forest and eastern fringe of the Warren Bioregion. Buddelundia species 8 was the most widely distributed and was collected from pitfall traps (Appendix 2).

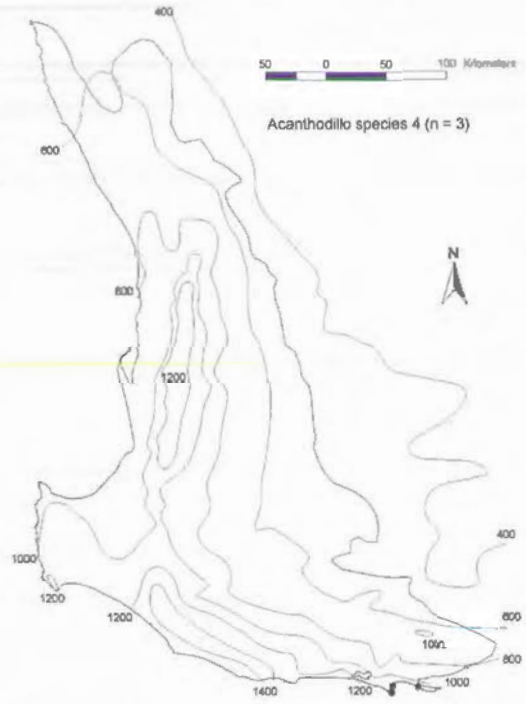
Unfortunately, there are no further microhabitat data for this species. Acanthodillo species 4 was collected from coastal karri forest in two National Parks in the Torbay (Locality 119) and Albany (Locality 120) and also occurred in pitfall traps (Appendix 2). The only record with microhabitat data for this species came from leaf litter. Cubaris species 4 appears to be a coastal since it was collected solely from under limestone rocks (Appendix 2) that characterise parts of the coastline in these localities. While data are sparse at this stage, it appears that microhabitat utilisation strategies might be similar to those of northern taxa.



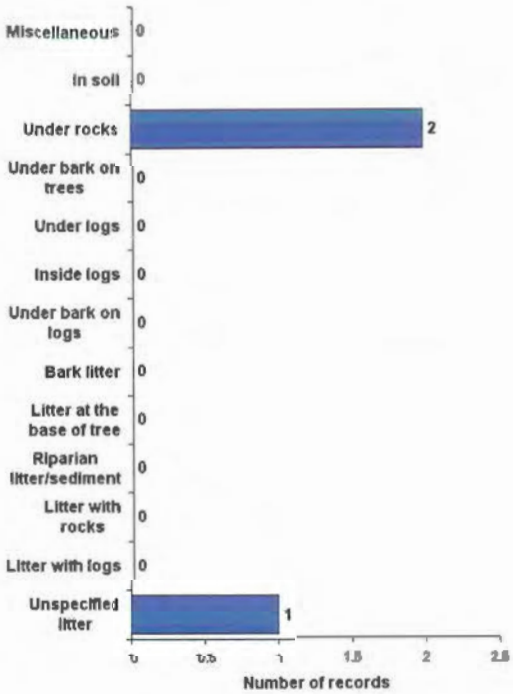
Local scale distribution of Buddelundia species 8.



Restricted scale distribution of Cubaris species 4.



Restricted scale distribution of Acanthodillo species 4.



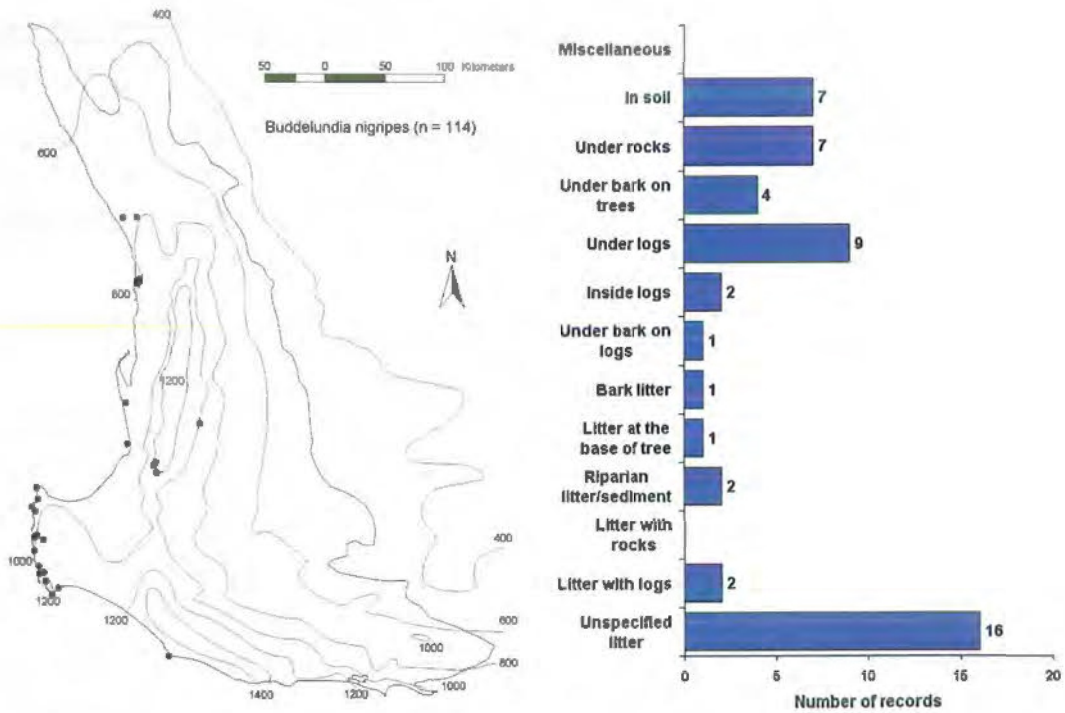
Combined total microhabitat utilisation for Buddelundia species 8, Cubaris species 4 and Acanthodillo species 4.

Figure 4.25. The local scale distribution of Buddelundia species 8, the restricted scale distributions of Cubaris species 4 and Acanthodillo species 4 and their combined microhabitat utilisation forming part of South-eastern Patterns. Raw data for species microhabitat utilisation are tabulated in Appendix 2.

4.10. UNCLEAR PATTERNS

The patterns of seven of the sixty taxa presented here were not easily classified. Since there appeared to be no single underlying reason for this, the possible explanations are discussed below in relation to the individual taxa.

The distribution of Buddelundia nigripes (Figure 4.26) is unusual and very interesting. The species is essentially coastally distributed and is particularly common in the Yallingup (Locality 57) and Leeuwin (Locality 85) localities. There are some inland outliers associated with the Collie River system and it occurs in remnant tuart (Eucalytus gomphocephala) woodlands in northern coastal parts of the Swan Coastal Plain. Specimens collected from Agonis flexuosa woodland in the Leschenault Conservation Park in the locality of Lake Preston (Locality 44), and very close to the type locality of Bunbury), are identical to the type specimen and accorded well with material found in tuart woodland in the localities of Perth (Locality 21) and Fremantle (Locality 25). Material from the Yallingup, Cowaramup (Locality 66) and Leeuwin localities regions differs markedly in overall markings and colour. Further examination and the inclusion of additional characters may better differentiate this form. This may be a coastal pattern but there is a lack of concordance with other taxa.



Sub-regional scale distribution of Buddelundia nigripes.

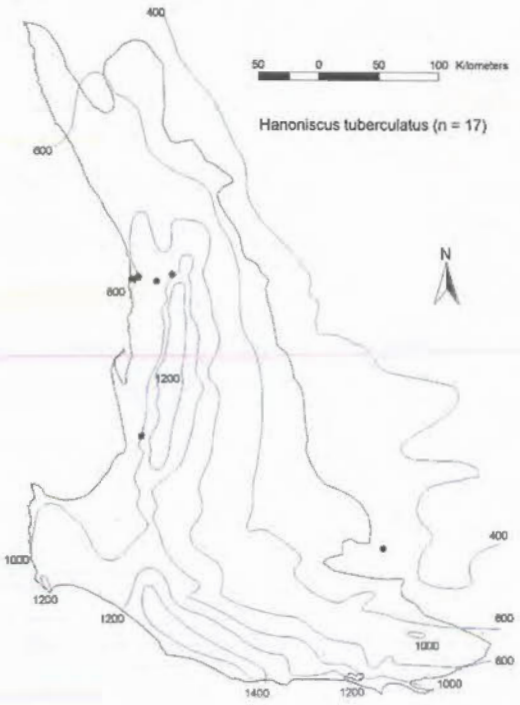
Total microhabitat utilisation for Buddelundia nigripes.

Figure 4.26. The sub-regional scale distribution and microhabitat utilisation of Buddelundia nigripes.

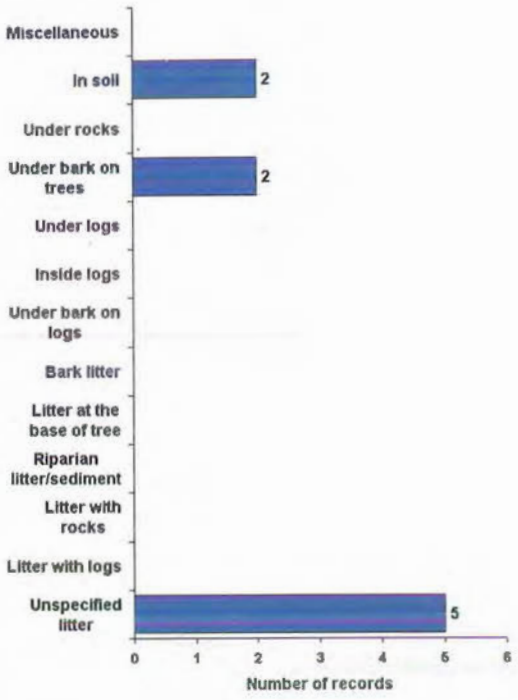
The only other taxon that was widely coastally-distributed was Hanoniscus new species (Figure 4.27), which occurs coastally in the Cowaramup and Leeuwin localities, and in southern parts of the Swan Coastal Plain. It was locally abundant at two sites at Hamelin Bay in the Leeuwin locality (Locality 85), the most southerly sites indicated on the distribution map. Here it occurred in litter, under karri bark and in soil at the base of coastal Agonis sp. shrubs in primary dune systems. The most northerly record came from under the bark of a paperbark (Melaleuca sp.) tree at the edge of a coastal salt lake. The species has a clear coastal distribution, although its precise nature is unclear. The distribution encompasses one of the type localities of H. nichollsi. Material from Bunbury, collected by the Hamburg expedition, and examined by Bowley (1935), was considered by her to be H. nichollsi. Re-examination of these specimens is necessary to determine the exact distribution of Hanoniscus new species and its taxonomic relationship with H. nichollsi Given the patterns so far described, it is likely that the specimens from Bunbury belong to the new species rather than to H. nichollsi, which appears restricted to high rainfall coastal forest in the Walpole area (Locality 108)

This study can add little to the distribution of Hanoniscus tuberculatus (Figure 4.27) published by Bowley (1935). Specimens from the Perth locality (Locality 21) and from Tambellup (outside the study area) mentioned by Bowley (1935) are present in the WAM material. Bowley (1935) suggested that H. tuberculatus occurs in swampy sites. Only one specimen was collected during this study and that was from under the bark of a tree at Benger Swamp Nature Reserve (Site 95) in the southern part of the Swan Coastal Plain (Locality 45). Swamps and dampland habitats were not routinely targeted and only incidental sampling resulted from this study. Therefore, since H. tuberculatus was not collected away from swampy sites, the observations of Bowley appear well founded. Obviously, the extent of the distribution of H. tuberculatus can only be determined fully following thorough collection in the littoral environments of selected swamps in the region. Given the patterns demonstrated previously, what seems certain however, is that H. monodi, represented in Northern Patterns, replaces H. tuberculatus in the northern part of the region.

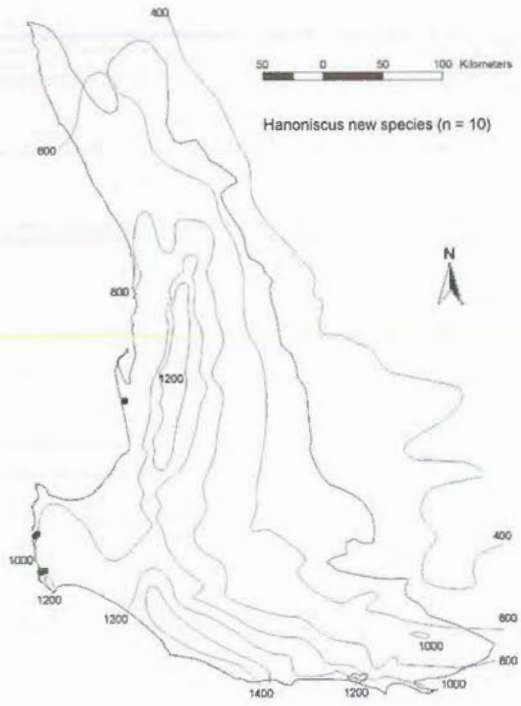
Eurygastor new species (Figure 4.28) appeared to be a litter dweller. The species is largely absent from the karri forest localities, except for its occurrence at some karri outliers in the Cowaramup (Locality 66) and Leeuwin (Locality 85) localities and the Porongurup Range (Locality 104). It is also found in the Stirling Ranges (Locality 201), the localities of Beraking (Locality 27) and Yaganing (Locality 31) in the Jarrah Forest east of Perth. In common with the forest dwelling Spherillo species 5, and both Pseudodiploexochus species 1 and 2, there appears to be a distinct north/south divide in its distribution.



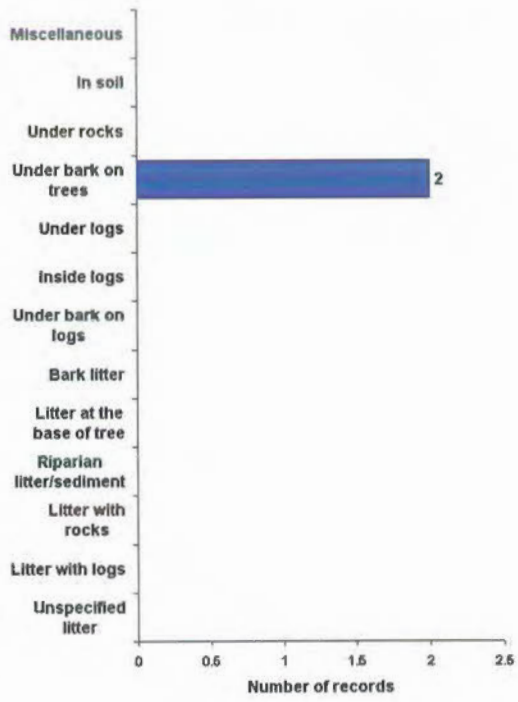
Sub-regional scale distribution of Hanoniscus tuberculatus.



Total microhabitat utilisation for Hanoniscus tuberculatus.

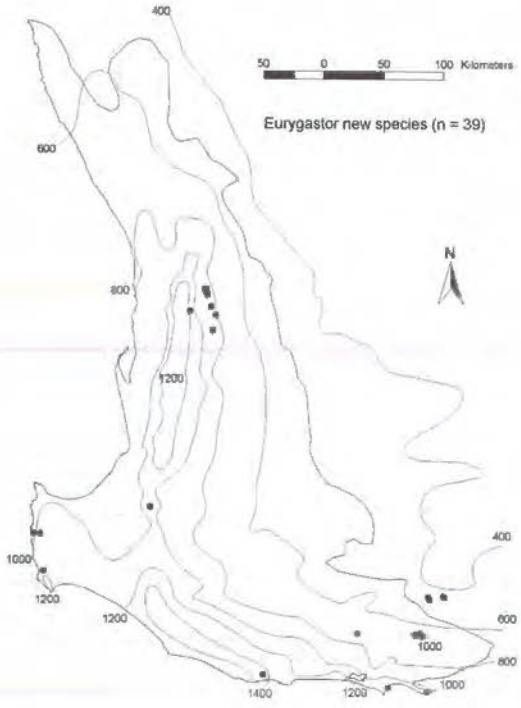


Local scale distribution of Hanoniscus new species.

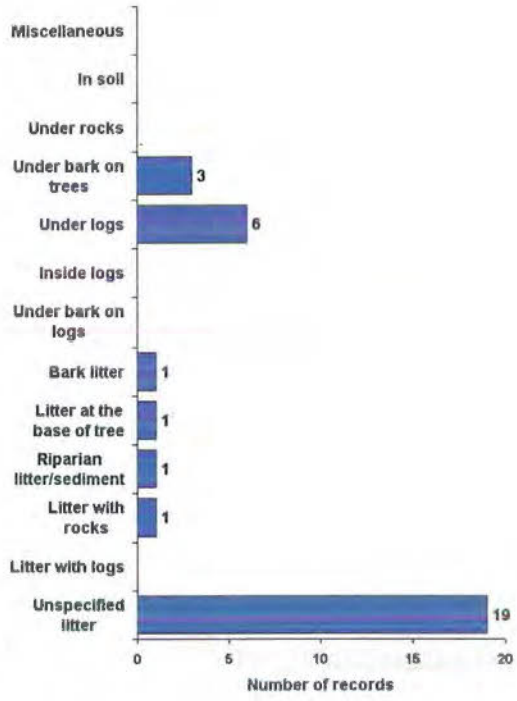


Total microhabitat utilisation for Hanoniscus new species.

Figure 4.27. The sub-regional scale distribution of Hanoniscus tuberculatus, the local scale distribution of Hanoniscus new species and their microhabitat utilisation.



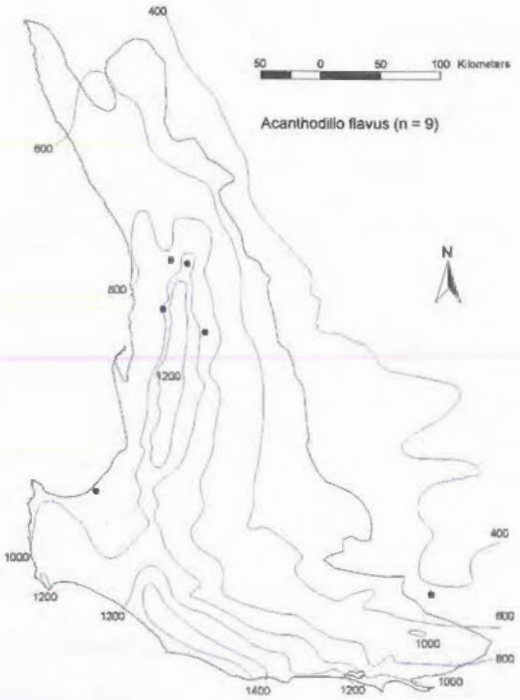
Sub-regional scale distribution of Eurygastor new species.



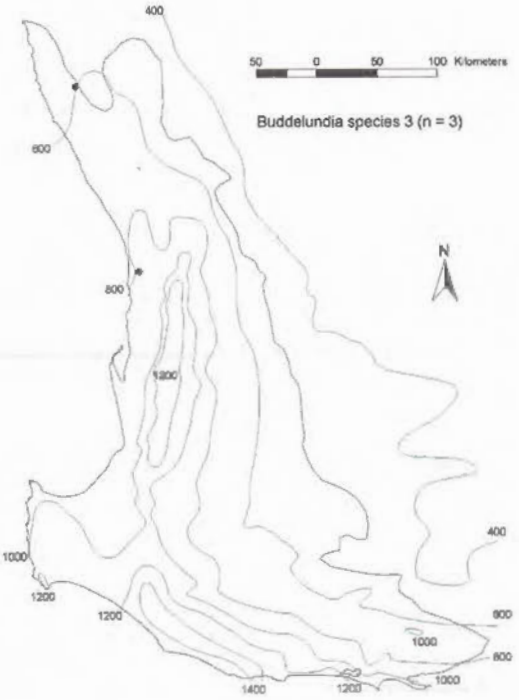
Total microhabitat utilisation for Eurygastor new species.

Figure 4.28. The sub-regional scale distribution and microhabitat utilisation of Eurygastor new species.

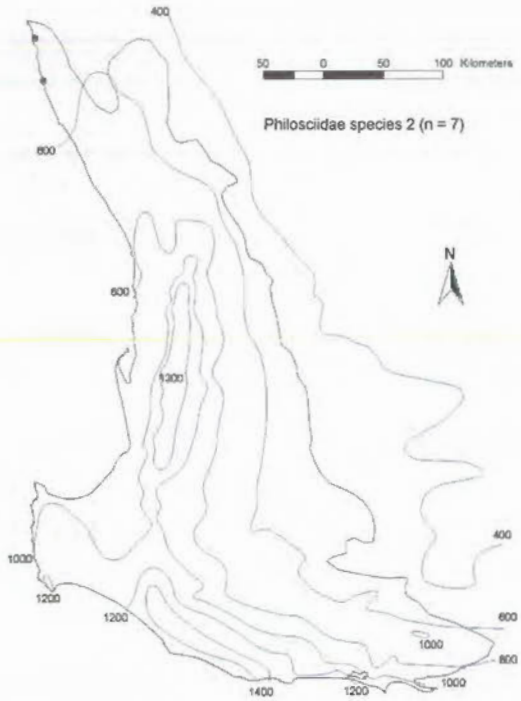
The distribution of Acanthodillo flavus, Buddelundia species 3 and Philosciidae species 2 is shown in Figure 4.29. The scant microhabitat data for these taxa are shown collectively. Acanthodillo flavus shows a concentration of records on the Ridge Hill Shelf landform at the foot of in the Darling Scarp in the Fremantle (Locality 25) locality and in the Jarrah Forest locality of Mundaring (Locality 22); the latter includes the type locality of Mundaring Weir. This species was not collected during the course of this study; therefore interpretations are based solely on the material in the WAM without the benefit of personal observation or systematically documented microhabitat data. Of the nine records present, two were without microhabitat data (Appendix 2). These were from Mundaring (close to the type locality) and the Stirling Range shown as the most southerly point. Five records came from pitfall traps all from Cardup Reserve, an locality of remnant woodland in good condition with abundant logs (Harvey et al., 1997a), one from Talbot Road reserve which, like Cardup Reserve, is also on the Ridge Hill Shelf landform, and one from Mt Cooke in the Yaganing locality (Locality 31) in the Jarrah Forest. The two records with microhabitat data were from under logs or rocks (Appendix 2).



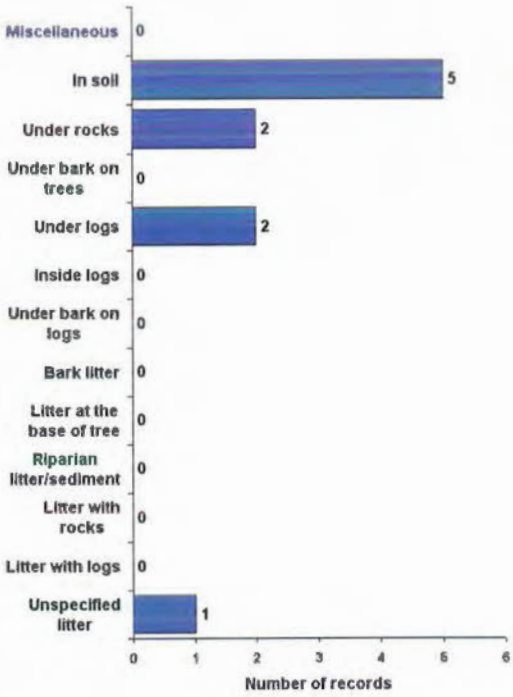
Sub-regional scale distribution of Acanthodillo flavus.



Local scale distribution of Buddelundia species 3.



Restricted scale distribution of Philosciidae species 2.



Combined total microhabitat utilisation for Acanthodillo flavus, Buddelundia species 3 and Philosciidae species 2

Figure 4.29. The sub-regional scale distribution of Acanthodillo flavus, the local scale distribution of Buddelundia species 3, the restricted scale distribution of Philosciidae species 2 and their combined microhabitat utilisation. Raw data for species microhabitat utilisation are tabulated in Appendix 2.

The record from the southern portion of the Swan Coastal Plain (the most south westerly point on the distribution map) is perhaps more interesting. The specimens were collected from under logs, in tuart forest at Ludlow (Locality 59), possibly by co-workers of Nicholls or Glauert. Museum labels indicate that they associated with nests of ants. The tendency of this genus to occur with ants and termites has already been noted in Sub-subsection 3.2.4.1. Indeed, most of the records for this genus in the region are from under rocks or logs. There is the distinct possibility that some of them are associated in some way with ants or more likely with modifications to the soil profile or logs decay facilitated by ants and termites.

Buddelundia species 3 was collected as part of this study from under logs at the margin of a seasonally wet dampland at the far the north of the Swan Coastal Plain. This species is very similar in general morphology to B. cinerascens but differs in some important characters. Two records come from the Perth locality, one of which, or possibly both, were collected from pitfall traps. These specimens are in poor condition; more material is required to determine both the distribution of this species and its relationship with B. cinerascens. It is possible that the specimen collected from the far-north of the region represents the southern limit of its distribution.

The last of the unclear distributions is that of Philosciidae species 2, which was found in association with two coastal salt lakes in the far north of the Swan Coastal Plain. It occurred in mostly saturated soil at the edge of the lakes and in litter in the littoral zone. This species has the distinct appearance of a secondarily aquatic species and was shown to survive in water (see its diagnosis in subsection 3.16.2). Its distribution can only be properly examined by concentrated sampling regimes on such environments. The diversity of such species has recently been discussed by Taiti and Humphreys (2002) and the distribution of Philosciidae species 2 is likely to be congruent with such aquatic features that persist in coastal environments of the northern Swan Coastal Plain Bioregion and northward. It could have been excluded from this analysis, since littoral and secondarily aquatic species were not examined. However, its distribution and microhabitat is uncertain at this stage and it is best noted in this section.

4.11. DISCUSSION OF PATTERNS

Terrestrial isopods are diverse and distributed widely throughout south-western Australia. Both their broad- and fine-scale distributional patterns imply a differing tolerance of species to environmental conditions, or different environmental or vicariant histories, different microhabitat preferences or local incipient speciation. The most widely distributed taxa were probably more mobile or occurred in a range of microhabitats. The regional scale patterns of Laevophiloscia and Styloniscus, whilst being informative at the generic level, are partly the result of the difficulty in species determination at this stage. In general, the greater the level of taxonomic resolution that was possible, the smaller-

scale these patterns became. Regional patterns at the generic level probably represent species patterns at all five scales.

One of the overriding features of the more widely distributed species was a north-south disjunction. This was shown for the regionally distributed Pseudodiploexochus species 1, the sub-regional Styloniscus species 7 and the sub-regional forest dweller Spherillo species 5. Further taxonomic discrimination of widely distributed species such as Laevophiloscia species 1 and 2, Eurygastor, Styloniscus species 1 and the Platyarthridae will probably emphasise this disjunction. It is clearly important and has been recognised in other crustacean taxa such as phreatoicid isopods (Wilson & Johnson, 1999) and talitrid amphipods (Judd, Horwitz & Jones, 1999). It will be discussed again in Chapter 8.

The north-south divide was emphasised by the presence of many taxa found only in the northern part of the region where there were definite associations with landforms. Buddelundia inaequalis and B. cinerascens are clearly coastal species. B. cinerascens is found as far north as the Cape Range in north-west Australia (Dalens, 1992) These species may require humid coastal conditions and/or may be salt dependent, particularly as other Buddelundia are associated with inland salt pans (Warburg, 1965, Judd, unpubl. data). Buddelundia from coastal and inland localities differ markedly from those found in forested regions. Dalens (1992) recognised two groups of Buddelundia and, based on the characters of the development of the frontal ridge, considered one primitive and one advanced. According to his classification, the advanced group is represented by the three species, B. inaequalis, B. cinerascens and B. opaca, as well as the northern Buddelundia species 3 and the eastern species 1. A more comprehensive survey of this widespread and unique genus would assist greatly in understanding regional oniscidean ecology. The availability of carbonaceous minerals may also be an important determinant of species distributions. The findings here are consistent with those of Tajovský (1998) who found higher species diversity in forests and steppes on limestone. Near-coastal parts of the Swan Coastal Plain with limestone outcropping were more species rich than adjacent sites on heavily leached sandy soils. This was even more apparent if the limestone localities supported remnants of tall eucalypt woodland.

An overriding influence in southern and central part of the region appeared to be rainfall. Local patterns resulting from steep rainfall gradients, created a mosaic of endemics in southern-forested localities. In high rainfall localities and within forested landscapes in general, it is clear that leaf litter is critical in the provision of microhabitat because all species contributing to high rainfall patterns occurred in leaf litter, or were collected from pitfall traps, and none from under stones It appears to be more important in the Jarrah Forest, because of the greater diversity of microhabitat possibilities offered by the wetter karri forest, although the importance of leaf litter in karri may increase during drier periods. In very wet areas, karri bark and the litter it produces are an important refuge from extremely moist conditions on the forest floor and probably the opposite in dry conditions. However, its importance may be overestimated because, compared to other

microhabitats, isopods can be located on the smooth, surface of karri trees following the removal of bark.

In contrast to the north of the region, where most taxa were locally distributed, the wet forest areas were noted for the presence of pockets of restricted endemics. These taxa were more specific in their microhabitat requirements and it appears that endemism occurs on a smaller scale in the wetter Jarrah Forest, due mainly to the presence of more single locality taxa, than in the wetter southern karri forests. In both these forest types, speciation may be a result of the historical expansion and contraction of moisture availability, an issue that will be explored in Chapter 8.

In wetter areas in particular, it is important to consider the scale of sampling when considering the scale of endemism evident. Both the richness and the scale of endemism in the Warren Bioregion may be influenced by the scale of the sampling. The area has high biodiversity with evidence of small-scale changes in ecological communities and endemism throughout the landscape (Hopper et al.,1992; Horwitz, 1997, Wardell-Johnson & Williams, 1996). The scale of sampling employed during this study may not have been sensitive enough to pick up all single locality taxa,[13] and what are described here as single locality may have less restricted distributions.

As well as leaf litter, logs were also essential to the provision of microhabitat. In lower rainfall localities there was less dependence upon leaf litter, decreasing mobility (occurrence in pitfall traps) and a greater utilisation of logs by some taxa. Logs perform a different role to leaf litter, and are important refugial sites for the xeric taxa in the more open woodlands in drier north-eastern parts of the region, and for outlying occurrences of forest species more commonly found in localities of higher rainfall. The presence of logs acts as a mesic refuge (Brown et al., 1996; Lindenmayer et al. 2002) allowing for the persistence of hygrophilic taxa in drier regions and for greater species diversity in wetter ones. Logs are important, not only as microhabitat in general, but also because the size, age and distribution of logs upon the forest floor influence the spatial distribution of leaf litter (Lindenmayer et al., 2002). Litter build-up next to logs influences the depth and density of litter and the degree to which litter is exposed to sunlight. Changes to the size and or distribution of logs on the forest floor are likely to affect not only log-dwelling taxa themselves but also litter dwellers.

The role of leaf litter on sandy coastal soils and rocky biotypes appears to differ from that in forested localities. Species restricted to coastal sites and those found in rocky biotypes were still common in leaf litter. The spatial distribution of leaf litter in these localities is likely to differ from forested localities, and the properties of leaf litter that are important in terms of microhabitat provision are likely to vary according to topography and superficial geology. The dependence upon leaf litter and logs by forest taxa suggests that they are

[13] Two such taxa (new species of Buddelundia and Acanthodillo) have since been discovered in karri forest near Pemberton

likely to be sensitive to changes in the temporal and spatial continuity of leaf litter and the nature of coarse woody debris. Chapter 7 investigates some of the properties of organic matter, how these properties vary geographically, and which are important to the provision of microhabitat.

Before this exploration, a clearer understanding of the determinants of terrestrial isopod distribution within the region is necessary. As outlined at the start of this chapter, the preceding sections have examined species range boundaries or, as stated by Whittaker et al. (2001), the species "envelope". The geographical boundaries of a species distribution are not static. Boundaries are spatially dynamic; they change as environmental conditions change (Brown, Stevens & Kaufmann, 1996). Channell and Lomolino (2000) argued that species distributional boundaries can contract, ultimately leading to local extinction, as a result of geographically dynamic extinction forces, spreading across the landscape like a contagion (the contagion hypothesis – sensu Lomolino & Channell, 1995). This hypothesis postulates that the last places impacted will those most isolated from the point(s) of infection. Contagions are considered to be anthropogenic disturbances. In most cases, the contagion is a suite of anthropogenic disturbances, including habitat degradation, biocides, xerification, and introduced species or pathogens (Lomolino and Channell, 1995). Therefore, humans can be considered vectors of this particular infection.

The degree to which these boundaries, and the holes within them, coincide, will determine patterns of species richness within a region. Sharp boundaries in species richness will always indicate concordance in the boundaries of a number of taxa, therefore creating potential landscape units in which similar processes are, or have been, governing the distribution of taxa. Such boundaries are determined in the next chapter, and along with the patterns of this chapter, will be used to construct a biogeographic model in Chapter 6. Chapter 7 and 8 examine some potential contagions.

It is important to recognise not only regional species richness, but also how local species richness contributes to it. The next chapter examines species richness and diversity at a range of scales. It is critically important to distinguish biogeographical factors relevant to the scale of diversity analysis (Koleff & Gaston, 2002). No matter how strongly we suspect an environmental factor to be important to perceived non-random distributions of a group of organisms, if that factor happens to exhibit no measurable variation across the geographical area of interest, it clearly cannot be causing any patterns demonstrated (Whittaker et al. 2001). However, there is no certainty that it hasn't done so in the past.

CHAPTER 5

DIVERSITY

5.1. INTRODUCTION

The concordant distributions of the previous chapter suggest that there are definable landscape units within the region in which processes are, or have been, acting upon a number of species in the same way. Before these biogeographical patterns can be used to construct a model, it is helpful to see how they combine to create patterns of species diversity. Patterns of species diversity are not simply the result of the accumulation of species over time. They are the result of a variety of ecological and evolutionary processes, historical events and geographical circumstances (Schluter & Ricklefs, 1993). Patterns of diversity in the landscapes of the present day are also the manifestation of coinciding species distributions.

At the start of the previous chapter the analogy of the species "envelope" was described (Section 4.1). Species diversity will vary spatially according to changes in the ranges of the contributing taxa but also due to the fact that there are often many more spaces than objects within the geographical range of many species (Whittaker et al., 2001). The first part of this chapter examines fine scale patterns of diversity, with the goal of determining factors likely to be important in the creation of objects and holes within the species ranges envelope. Then species diversity is analysed at two broader scales, in order to identify areas of high and low diversity, the boundaries created by such areas, and some of the factors that explain them.

The simplest measure of species diversity is to count the number of species within a defined geographical area. This is termed species richness. Species richness will increase in direct relation to the number of individuals sampled, the area sampled, and the diversity of habitats included within the sample area (Schluter & Ricklefs, 1993).

Differences in sampling methods can result in statistical and ecological biases when comparing species richness among a range of differing sites, localities or regions. Therefore, in terms of this study, and in order to establish a reliable biogeography, two assumptions are made. The first is that patterns observed are not an artefact of the dataset, in other words, that patterns are not generated from biases in the data due to their age, origin or the manner in which they have been compiled, and the second is that all taxa present have an equal chance of being recorded in all parts of the region. These assumptions are tested at the end of this chapter.

In order to construct a biogeographic model from the data presented here, it is essential first to evaluate the nature and extent of the dataset. Therefore, the penultimate part (Sections 5.6) of this chapter examines in detail the relationship between some elements of the data and patterns of diversity they create. Both the number of records, and the manner in which they may have been acquired, have the potential to create artificial patterns. Therefore, a broad-scale case study of the relationship between high diversity and abundant records is made, to see what influence a geographical concentration of records has upon the patterns of richness. Following this, Section 5.6 also addresses the

efficacy of the methods. It is important that the methods chosen for the stratified regional sampling undertaken during this study, collected all, or as many as possible, of the region's Oniscidea. To this end, all the collecting methods are examined for their contribution to the dataset. The final section (Section 5.7) summarises the important findings of the chapter and highlights the information important to the next chapter. The aims of this chapter are to:

- examine patterns of richness at various scales, see if they differ and why;
- suggest some of the possible regional factors responsible for patterns of richness;
- examine the relationship between the number of data points and nature of the data on patterns of species richness;
- establish the efficacy of the collection methods used; and,
- assess whether biases in the data set are likely to influence any biogeographical patterns generated from it.

5.2 THE QUESTION OF SCALE

The question of scale is fundamental to understanding patterns of richness. The partitioning of diversity in various scale units is central to the understanding of the contribution of large-scale processes to local diversity (Schluter & Ricklefs, 1993). Since different environmental factors exhibit measurable heterogeneity at different scales (Whittaker et al., 2001), the development of scales by which diversity can be assessed provides a framework for understanding the connections between local and regional species richness.

Specific terminology has been developed for measuring diversity at a range of spatial scales (e.g. Cody, 1975; Whittaker, 1977). The names given to various scales of species richness inventory are not always consistent between authors. There are two commonly recognised generic scales at which species richness is counted and used to represent diversity; these are the local scale and the regional scale. The actual geographical areas of the "local scale" unit or the "regional scale" unit vary with the author's interpretation of the terms, the derivation of the scheme being used, the degree of landscape heterogeneity (Koleff & Gaston, 2002) and with the taxon being studied. The precise scale chosen is often a matter of convenience. Authors commonly adopt the scale at which the data inventory had been compiled as the scale of diversity analysis (Whittaker et al., 2001). Such discussions permeate the literature, and the relative merits of various schemes have been recently reviewed (Whittaker et al., 2001) with a view toward a general hierarchical theory Regardless of scheme or author, the first five letters of the Greek alphabet (alpha α, beta β, gamma γ, delta δ, epsilon ε) are usually used to indicated an ascending spatial scale of diversity. While arguments as to the appropriate scales for species richness inventories continue, one distinction made by Whittaker

(1977) remains of fundamental importance. That is, species diversity consists of two components; the initial inventories (species richness) and the degree to which these may change among different inventories (compositional turnover).

Of all the scale hierarchies available, the choice for analysis depends usually upon the taxa and the spatial scale of the inventory undertaken. The analysis here follows the scheme of Whittaker (1977). The principle reason for this is that it includes a microscale, a hierarchical tier below that of the lowest usually present. The scheme includes five tiers, three of inventory diversity and two of differentiation diversity and are shown in Table 5.1. Due to the confusion in the literature surrounding the uses of the terms alpha, beta and particularly gamma diversity (Koleff and Gaston, 2002), analysis uses generic terminology since it provides for a more intuitive framework (Whittaker et al., 2001). Terms and scales are shown in the final column in Table 5.1.

Table 5.1

Seven hierarchical tiers incorporating two types of species diversity adapted from Whittaker (1977). The terms and scales used here are given in the final two columns.

	Inventory Diversities		Differentiation Diversities	Scale of data Collection	Generic term used here
1.	For a small or microhabitat sample within a community regarded as homogeneous, internal alpha or sub-sample diversity, point diversity			Site (~0 01 km^2)	Point Diversity
		2.	As change between parts of an intra-community pattern, internal beta or pattern diversity		Microhabitat differentiation
3.	For a sample representing a community regarded as homogeneous (despite its internal pattern), alpha or within habitat diversity			Locality (~650 km^2)	Local Diversity
		4	As change along an environmental gradient or among the different communities of a landscape, beta or between habitat diversity		Landscape Differentiation.
5	For a landscape or a set of samples including more than one community, landscape or gamma diversity (variously used as any convenient large unit (Rosenzweig, 1995)).			Composite Landscape Unit (~2500 km^2)	Landscape Diversity
		6	As change along climatic gradients or between geographic areas, geographic differentiation or delta diversity		Geographical Differentiation
7	For a broader geographic unit including differing landscapes, regional, (epsilon) diversity			Darling Botanical Distnct (~75,000 km^2)	Regional Diversity

5.2.1. INVENTORY DIVERSITIES

Chapter 2 (Section 3.2.1) showed a geographical framework by which a stratified collection regime was employed, and by which the data were grouped. This framework of localities is intrinsically part of the data structure. Wherever possible the sampling strategy included at least one sampling site within each locality, and most localities were sampled more than once. The first scale examined is that of the sampling carried out during this study. The species richness of the sampling sites is used to represent point diversity. Sites are considered representative of point diversity and not alpha (local) diversity because they do not encompass the full range of landscape variation on a local scale. A single site cannot represent either the full range of potential microhabitat types, or the likely variability within their properties. Point diversity analysis only includes data from material collected during this study.

The one hundred and twenty localities and the three supplementary localities that formed the framework for data analysis, create the second hierarchical scale of inventory diversity, alpha diversity or, as it is termed here, local diversity. Local diversity is measured as the number of species occurring in each of these localities. The scale of the locality unit (~650 km^2) is large enough to encompass variation with topographical and vegetative differences and variations in disturbance regimes among sites of point diversity, but not large enough to detect difference in macro factors, such as latitudinal variation, rainfall, and gross landform differences. Inventory diversity at the locality scale is therefore likely to be representative of factors that vary measurably on local scales.

Finally, inventory diversity is examined at a landscape scale. In Subsection 2.3.1 twenty-nine landscape units (LUs) of approximately equal area were derived. They were created by combining adjacent localities and were listed and named in Table 2.2. Landscape Diversity was measured as the taxa richness occurring within these units. The landscape units are simply convenient geographical areas and their sole purpose was for the analysis in this chapter. Following analysis of the different scaling levels of diversity combined with the geographical patterns presented in the last chapter, more appropriate, or natural landscape units will be derived in the next chapter. As with locality diversity, analysis of local and landscape diversity includes data generated by this study and from the WAM collection. The names of both localities and LUs are used frequently throughout the remainder of this chapter. As with the previous chapter, the locality or LU number is given in parentheses.

5.2.2. DIFFERENTIATION DIVERSITIES

The methods for calculating differentiation diversities followed those outlined by Whittaker (1977, p.4), and are summarised here. The extent of change in species composition among sites of point diversity within a locality was considered to be the smallest scale of differentiation diversity. This is termed "microhabitat differentiation". It was calculated by dividing the number of species occurring one or more times in the set of samples

(aggregate point diversity) within the alpha inventory unit (Locality) by the mean number of species for that set of point inventories.

Beta diversity, or landscape differentiation as it is termed here, was calculated in the same way as microhabitat differentiation. Landscape diversity, or the total number of species occurring one or more times in each of the alpha inventory units combined to form the landscape unit, was divided by the mean number of species for the contributing alpha units. Geographical differentiation, measured as the extent of species change between landscape units with the region, is examined in more detail in Chapter 8, after more natural landscape units have been determined in the following chapter.

5.3. POINT DIVERSITY

The value of an examination of point diversity stems from the facts that sites were all the same size, thereby controlling the variable of area, and the same collecting methods and effort were employed at each site. This, to some degree, avoids the collection bias and artefactual patterns in point diversity. Figure 5.1 shows the frequency of each value of point diversity among the sites sampled, and Figure 5.2 shows the point diversity plotted according to the location of the sites sampled. Table 5.2 shows the point diversity of each of the sites within the locality in which they occurred, aggregate point diversity, the mean point diversity recorded within each locality and microhabitat differentiation.

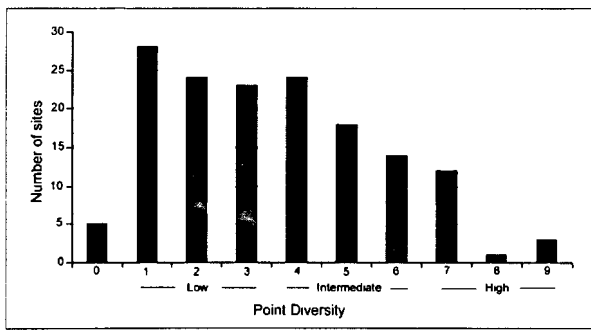


Figure 5.1. The frequency of point diversity among the sites sampled during this study. Sites were classified according to whether they had low, intermediate or high diversity, a classification also given in Figure 5.2.

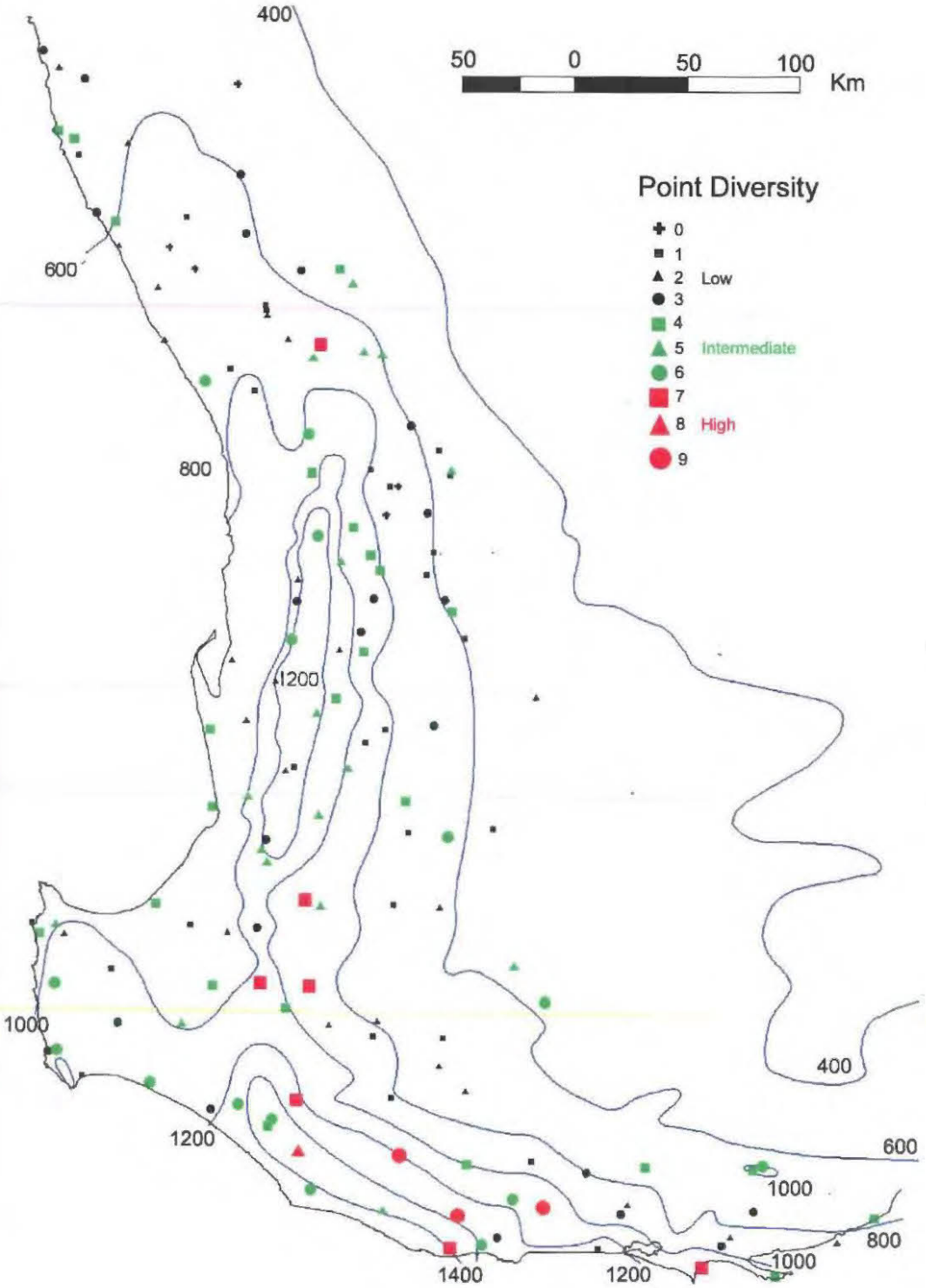


Figure 5.2. The point diversity of the sites sampled during this study. Black indicates sites of zero or low point diversity, green intermediate and red sites of high point diversity. This classification corresponds with that of Figure 5.1.

Table 5.2

Point diversity represented by species richness of sites sampled during this study. Only those localities from which taxa were recorded are included. The locality number is shown in the first column. The numbers of the sites, representing the points sampled, occurring in the locality (listed in Appendix 1a and plotted in Figure 2.1 & 2.2) are shown columns 2 to 4. The species richness, or point diversity, of these sites is listed in the corresponding columns 5 to 7. Mean point diversity for each locality containing more than one site is given in column 8. Aggregate point diversity is the number of different species found at all sites within that locality and microhabitat differentiation, shown in the last column, is calculated by dividing aggregate point diversity by mean point diversity.

Locality	Site Number in Locality (Point Sampled)			Point Diversity				Aggregate Point Diversity	Microhabitat Differentiation
	#1	#2	#3	#1	#2	#3	Mean		
1	48	49	-	1	3	-	2.00	4	2.00
2	16	-	-	0	-	-	-	0	-
3	50	52	53	4	1	3	2.67	5	1.88
4	51	-	-	2	-	-	-	2	-
5	35	-	-	3	-	-	-	3	-
6	17	18	19	1	2	3	2.00	6	3.00
7	15	20	-	1	0	-	0.50	1	2.00
8	36	-	-	3	-	-	-	3	-
9	54	-	-	2	-	-	-	2	-
10	21	-	-	0	-	-	-	0	-
11	38	39	40	1	1	2	1.33	3	2.25
12	44	45	-	4	3	-	3.50	5	1.43
13	55	-	-	2	-	-	-	2	-
14	34	56	-	1	2	-	1.50	2	1.33
15	22	57	-	5	7	-	6.00	10	1.67
16	41	42	-	4	4	-	4.00	7	1.75
17	46	-	-	6	-	-	-	6	-
18	37	-	-	1	-	-	-	1	-
19	31	-	-	5	-	-	-	5	-
20	58	-	-	3	-	-	-	3	-
22	23	24	-	4	5	-	4.50	6	1.33
23	4	5	8	0	1	1	0.67	2	3.00
24	60	61	-	1	5	-	3.00	6	2.00
26	32	43	77	6	5	5	5.33	12	2.25
27	6	7	76	4	0	3	2.33	6	2.57
28	62	63	-	2	1	-	1.50	2	1.33
30	9	10	-	2	3	-	2.50	4	1.60
31	78	79	-	3	4	-	3.50	5	1.43
32	64	65	66	4	3	1	2.67	6	2.25
34	88	106	-	2	2	-	2.00	3	1.50
35	11	86	-	6	2	-	4.00	6	1.50
36	80	81	-	3	4	-	3.50	5	1.43
37	67	-	-	1	-	-	-	1	-
38	89	-	-	4	-	-	-	4	-
39	87	-	-	2	-	-	-	2	-
40	82	83	-	4	5	-	4.50	6	1.33
41	84	85	-	1	1	-	1.00	2	2.00
42	68	-	-	3	-	-	-	3	-
43	33	-	-	2	-	-	-	2	-
44	94	-	-	4	-	-	-	4	-
45	95	147	-	5	2	-	3.50	6	1.71
46	96	97	-	5	1	-	3.00	5	1.67
47	74	-	-	4	-	-	-	4	-
51	12	13	14	5	5	3	4.33	6	1.38
52	75	-	-	5	-	-	-	5	-
53	90	-	-	1	-	-	-	1	-
54	73	-	-	6	-	-	-	6	-
55	69	-	-	1	-	-	-	1	-
57	1	107	108	5	2	4	3.67	8	2.18
58	93	-	-	4	-	-	-	4	
59	99	-	-	1	-	-		1	
60	98	105		2	3	-	2.5	4	1.60
61	91	92	-	5	7	-	6.00	8	1.33
63	72	-	-	2	-	-	-	2	-
66	115	-	-	6	-	-	-	6	-
67	109	-	-	1	-	-	-	1	-
68	103	-	-	3	-	-	-	3	-
69	104	-	-	7	-	-	-	7	-
70	100	-	-	7	-	-	-	7	-
73	71	-	-	5	-	-	-	5	-
76	113	114	-	3	6	-	4.50	7	1.56
77	110	-	-	3	-	-	-	3	-
78	102	-	-	5	-	-	-	5	-

Table 5.2
(continued)

Locality	Site Number in Locality (Point Sampled)			Point Diversity				Aggregate Point Diversity	Microhabitat Differentiation
	#1	#2	#3	#1	#2	#3	Mean		
79	101	-	-	3	-	-	-	3	-
80	30	-	-	2	-	-	-	2	-
81	137	139	-	1	1	-	1.00	2	2.00
82	140	-	-	1	-	-	-	1	-
84	70	-	-	6	-	-	-	6	-
85	111	-	-	1	-	-	-	1	-
86	112	-	-	5	-	-	-	5	-
87	27	-	-	3	-	-	-	3	-
88	26	28	29	6	6	-	6.00	8	1.33
89	29	-	-	7	-	-	-	7	-
90	138	-	-	1	-	-	-	1	-
91	141	142	-	2	2	-	2.00	3	1.50
96	25	-	-	4	-	-	-	4	-
97	145	-	-	8	-	-	-	8	-
98	143	-	-	9	-	-	-	9	-
99	136	-	-	4	-	-	-	4	-
100	131	-	-	1	-	-	-	1	-
101	132	-	-	3	-	-	-	3	-
102	125	-	-	4	-	-	-	4	-
104	116	117	-	6	4	-	5.00	6	1.20
105	146	-	-	6	-	-	-	6	-
106	144	-	-	5	-	-	-	5	-
107	133	-	-	9	-	-	-	9	-
108	134	135	148	5	6	2	4.33	8	1.85
109	130	-	-	9	-	-	-	9	-
110	128	129	-	2	3	-	2.50	4	1.60
111	118	-	-	3	-	-	-	3	-
112	120	124	-	2	2	-	2.00	3	1.50
113	123	-	-	2	-	-	-	2	-
114	122	-	-	4	-	-	-	4	-
115	126	-	-	6	-	-	-	6	-
117	127	-	-	1	-	-	-	1	-
119	119	-	-	7	-	-	-	7	-
120	121	-	-	4	-	-	-	4	-

Obviously, only localities with more than one measure of point diversity were included in the calculations of microhabitat differentiation. The two figures and table include only species collected during this study. Therefore, aggregate point diversity shows the number of taxa collected within each locality as part of this study. Aggregate point diversity is different from locality diversity, as defined in the previous section, and discussed in the next. It is shown here because it was needed to calculate microhabitat differentiation.

Terrestrial isopods were absent from only five of the sites. Between one and nine taxa were collected from each of the remaining sites. The modal value was one taxon but there was little difference between the frequency of sites with 1, 2, 3 and 4 taxa. The mean number of taxa per site was 3.42. The number of sites drops steadily and evenly between 4 and 7 taxa (Figure 5.1). Sites with no terrestrial isopods were in all drier vegetation types, two on the eastern margin of the jarrah forest and three in Banksia woodland on the northern part of the Swan Coastal Plain. For the purposes of examining patterns of diversity at this scale, the remaining sites have been classified into three class sizes. Sites with 1-3 taxa are considered to have low point diversity, sites with 4-6 taxa are considered to have intermediate point diversity and sites with 7-9 taxa are considered to have high point diversity.

5.3.1. CHARACTERISTICS OF HIGH POINT DIVERSITY

Only eleven (7.4%) of the sites sampled had high point diversity. The richest sites were, generally speaking, the far south of the region and in some higher rainfall localities of the jarrah forest. Nine taxa were collected from three sites (Sites 130,133 & 143) in karri forest in the far south of the region in the Owingup, Deep River and Shannon (Localities 109, 107 and 98) respectively. Eight taxa were recorded for only one site (Site 145), in the main belt of karri forest in the Northcliffe locality (Locality 97), immediately to the west of the three richest sites. Sites with seven taxa occurred in the south of the region in the karri forest at Site 29 in the Pemberton locality (Locality 89), at an easterly outlier of karri at Site 119 in the Torbay locality (Locality 119) and in the high rainfall tingle (Eucalyptus brevistylis, E. guilfoylei) forest at Site 126 in the Mount Frankland locality (Locality 108). Three closely grouped sites (Site 92, 100 & 104) also had seven taxa. Two of these, Sites 100 and 104 were adjacent sites in well-elevated jarrah forest in the Ballingup and Bridgetown localities (Localities 69 and 70), while the third, Site 92, was further north in a significant remnant of old growth jarrah forest in the Wilga locality (Locality 61). A significant outlier in the distribution of sites with seven taxa occurred at Site 57 in the Chittering locality (Locality 15). This site was on the western slopes of Mount Byroomaning, a significant geological feature in the north of the region, which is well wooded and has much granite outcropping.

The overall characteristic of the eleven sites with high point diversity is that they are all heavily wooded. Ten of the sites received close to, or more than, 1000 mm annual rainfall and seven of them were within the distribution of karri (Eucalyptus diversicolor).

5.3.2. CHARACTERISTICS OF INTERMEDIATE POINT DIVERSITY

Fifty-nine sites (39.9%) displayed intermediate point diversity. The richer of the intermediate diversity sites, those with six taxa, were all generally in forested localities and predominantly in the south of the region. Of these fifteen sites, all but four were within the 1000 mm isohyet. The most northerly site, Site 46, in the Yanchep locality (Locality 17) was coastal tuart forest at Yanchep National Park. Another northerly site, Site 31 in the Jumperkine locality (Locality 19) was in granite slopes of the Darling Scarp at Walyunga National Park. This site shared many of the characteristics of the high point diversity Site 57 at Mount Byroomanning. Above average point diversity of sites associated with the Darling Scarp, was also seen in Sites 32 and 11 in the Kelmscott and Jarrahdale (Localities 26 & 30). Two other sites of significant intermediate point diversity were Site 73, a small remnant of Wandoo woodland in the east of the region in the Darkan locality (Locality 54) and one of the easterly sites, Site 70, a remnant of jarrah and marri woodland in the Uannup locality (Locality 84). These last two sites are significant in that they occurred in localities of much lower rainfall.

Eighteen sites, with five taxa, were distributed within the region's forests. Of these, very few were found in the south of the region and there were no sites close to the coast.

Most were distributed throughout the jarrah forest, both within the highest rainfall localities and in drier north-eastern parts. Sites with four taxa were also common throughout the Jarrah Forest Bioregion. Drier eastern parts of the jarrah forest, if not of low point diversity, usually had four taxa, as did most of the wooded sites on the coastal fringe of the Swan Coastal Plain Bioregion

5.3.3. CHARACTERISTICS OF LOW POINT DIVERSITY

Seventy-five (50.7%) of the sites, had low point diversity Only sixteen of these sites were in localities receiving higher than 1000 mm annual rainfall Nearly a quarter (17) of these were in the Swan Coastal Plain north of the 800 mm isohyet, and nearly half (36) were sites in the jarrah forest receiving less than 1000 mm annual rainfall.

5.3.4 MICROHABITAT DIFFERENTIATION

With regard to microhabitat differentiation, probably the most significant feature of Table 5 2 is that none of the localities had a microhabitat differentiation equal to one. A microhabitat differentiation equal to one would indicate that the mean point diversity was equal to the aggregate point diversity. In other words, every point sampled within that locality would have had an identical composition of terrestrial isopods. Terrestrial isopod assemblages differ, either dramatically, or subtly, over short distances. This variability suggests that small-scale environmental variations, such as site conditions, the presence of microhabitats and their properties, are important determinants of terrestrial isopod distribution at the smallest inventory scales.

There was no apparent relationship between local diversity and microhabitat differentiation The extent of change in species composition between microhabitat samples within a relatively small area is not related to the number of taxa found in that locality However, in general, the greater number of points sampled within a locality, the greater the microhabitat differentiation The twenty-seven localities, within which two point diversity samples were made, had a mean microhabitat differentiation of 1.45 while the ten localities, from which three point diversity samples were made, had a mean microhabitat differentiation 2.26 These two means were statistically significantly different when compared using a t-test for samples with unequal variances ($t = 1.795$, $df = 11$, $p = 0.002$) This suggests that microhabitat differentiation increases with the number of microhabitat samples within a given geographical alpha unit This urges caution in interpreting the measure of microhabitat differentiation seen here Caution is also necessary because not all localities (alpha units) had more than one sampling site Therefore, as a case study, and in order to be consistent, microhabitat differentiation is evaluated for those localities where three point inventories were made These localities are Cervantes (Locality 3), Walyengarra (Locality 6), Mindarra (Locality 11), Chidlow (Locality 23), Kelmscott (Locality 26), Beraking (Locality 27), Luptons (Locality 32), Burekup (Locality 51), Yallingup (Locality 57) and Mount Frankland (Locality 108). The

relationship between aggregate point diversity and microhabitat differentiation for these localities is shown in Figure 5.3

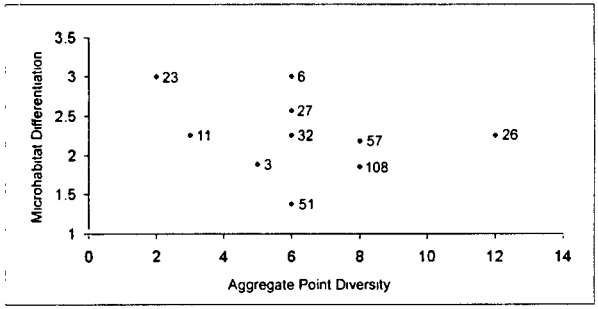


Figure 5.3. The relationship between aggregate point diversity and microhabitat differentiation for those localities that included three samples of point diversity. The number of each locality is shown on the appropriate point on the graph.

Two localities, Walyengarra (Locality 6) and Chidlow (Locality 23), both in the north of the region receiving between 600 and 800 mm annual rainfall, recorded the highest microhabitat differentiation The three sites (Sites 17, 18 & 19) within the coastal Walyengarra locality were very close geographically (See Figure 2.3) but had a suite of species unique to each site, and recorded one, two and three species respectively. This probably reflects the diversity of landforms close to the coast, in which microhabitat utilisation is diverse and can change over small geographical ranges. Within the Chidlow locality the microhabitat differentiation was also high but for a different reason, i e only two taxa were recorded from three sites. This reflects the pattern of low point diversity found in the northern parts of the region shown in Figure 5 2

Figure 5.3 shows a range of coastal localities (Localities 3, 6 & 57), northern forest/woodland localities (Localities 11, 23, 26, 27 & 32) a central jarrah forest locality (Locality 51) and southern forest locality (Locality 108) The range of aggregate point diversities and microhabitat differentiation suggests that the extent of change in species composition between microhabitat samples is consistent throughout the region. Take for example the five northern forest/woodland localities. They display a range of aggregate point diversities from two to twelve taxa and all have similar microhabitat differentiation Only two localities, the adjacent localities 27 and 32, are similar The differences in inventory and differentiation diversity among sites is a reflection of both the number of taxa represented in Northern Patterns described in the previous chapter, and their wide range of microhabitat utilisation

5.4. LOCAL DIVERSITY

The following section examines local diversity derived from both the material discussed in the previous section and WAM material. Figure 5.4 illustrates local diversity, measured by species richness of the 120 localities and the three supplementary localities. The map is schematic and the colour scheme shows the richest localities in red and the least rich in blue. The local diversity value (taxa richness) is also shown in each locality square and a key to locality numbers is included.

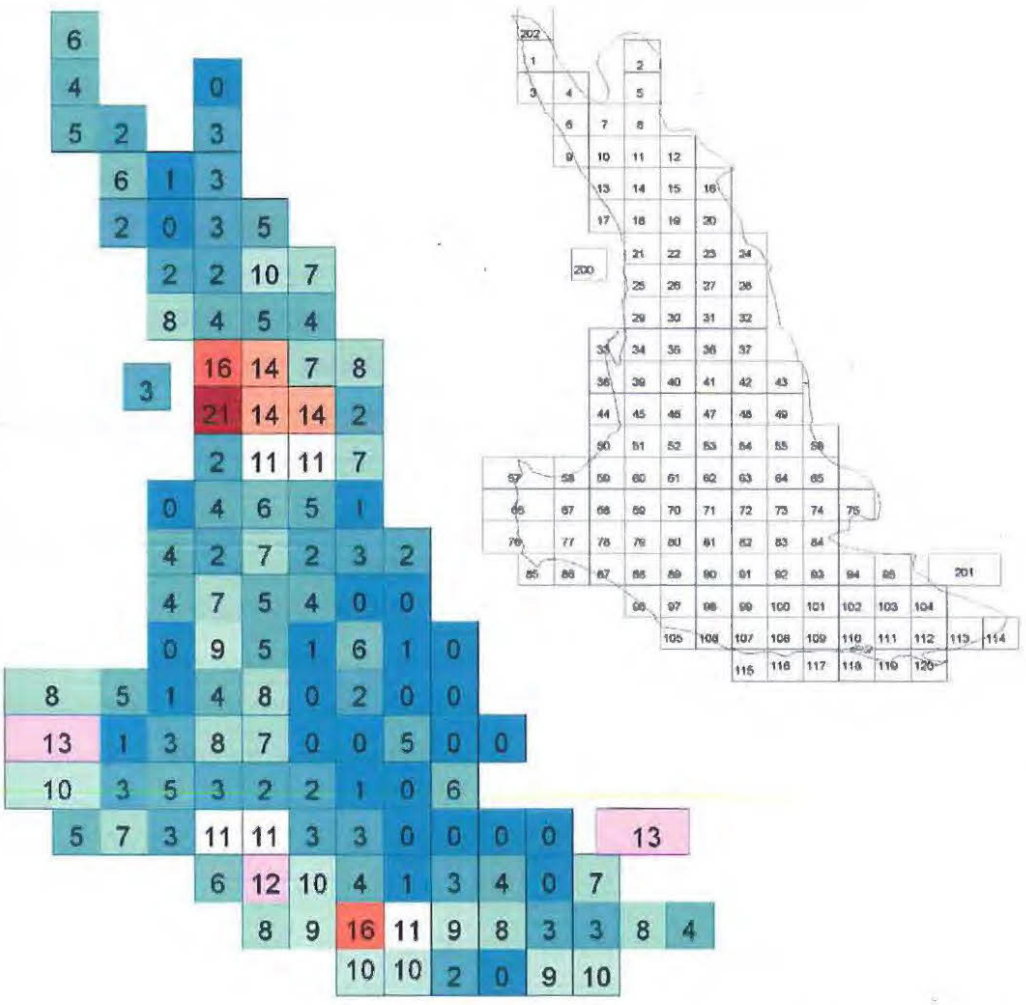


Figure 5.4. A schematic representation of local diversity. Local diversity was measured by recording the number of taxa found in each of the localities shown. The colour scheme shows zero diversity in dark blue progressing to white for intermediate diversity and through pink to red for higher diversity. Inset is a key to the locality numbers used in Tables 5.2 and 5.3 and the describing text.

The most diverse locality is Fremantle (Locality 25) with twenty-one taxa. It is significantly more diverse than the next highest two localities, the adjacent Perth locality (Locality 21) and in the far south the Deep River (Locality 107), both of which had sixteen taxa. Adjacent to Perth, the Mundaring (Locality 22) and Kelmscott (Locality 26) localities were also relatively diverse having fourteen and eleven taxa respectively. These

localities reflect some of the high point scale diversity found on the Darling Scarp shown in Figure 5.1 and in the case of Mundaring, high aggregate point diversity as shown in Figure 5.3.

Locality diversity in the south of the region was not as high as that in the Perth and Fremantle localities. Nevertheless, these two very diverse localities aside, there were localities of high diversity in both the north and south of the region. In the north, the Mundaring (Locality 22) and Kelmscott (Locality 26) localities had fourteen and eleven taxa respectively, whilst in the south, Northcliffe (Locality 97) had twelve taxa, Charnwood (Locality 88) and Pemberton (Locality 89) eleven, and Shannon (Locality 98) had ten taxa. The six richest localities in the south of the region: Charnwood, Pemberton, Northcliffe, Shannon, Deep River (Locality 107) and Mount Frankland (Locality 108) represent the main distribution of karri forest and correspond well with the distribution of high and higher intermediate point diversity sites shown in Figure 5.2. For example, the sixteen taxa present in the most diverse southern locality of Deep River correspond with the maximum point diversity of nine taxa found at Site 133. Northcliffe, the second richest locality in the south of the region with twelve taxa, contained Site 145, the only site with a point diversity of eight. The other two sites with highest point diversity of nine, Sites 130 and 143, accounted for all or nearly all, of the diversity of the localities in which they occurred. Sites 130 occurred in the Owingup (Locality 109) with a local diversity of ten and Site 143 in the Shannon locality which had a local diversity of nine.

Cowaramup (Locality 66), much further west than the most diverse southern localities, also had high diversity. It was the second most diverse locality within the southern part of the region, and was more diverse than all karri forest localities except Deep River (Locality 107) However, the site in this locality sampled during the present study, only recorded high intermediate point diversity of six taxa. The locality is well represented by WAM material from two small-scale intensive studies of woodland and coastal swamps This suggests that small-scale landform variation may be important to local diversity in this part of the region. Therefore, the Yallingup (Locality 57), Karridale (Locality 76) and Leeuwin (Locality 85) in this westerly part of the Warren Bioregion, may be richer in taxa than Figure 5 4 indicates. All localities contain a range of forest and woodland types, including outlying karri, and have unique and varied coastal geomorphological features including cave systems. The Karridale locality included both a coastal (Site 113) and adjacent forest site (Site 114), and between them, recorded seven of the ten taxa recorded from the locality. The fact that there were no sites of high point diversity in the four localities in this area, indicates that, like the north of the region, the extent of change in species composition over very short-scales is likely to be considerable

The Stirling Range (Supplementary Locality 201) had a remarkable number of taxa considering that the locality receives approximately 600 mm annual rainfall, less than half that of the karri forest. Nevertheless, it had an identical number of taxa (12) as Northcliffe (Locality 97), one of the richest parts of karri forest. The Stirling Range is a large

National Park and the highest mountain range in south-western Australia. The influence of this feature is obvious. The locality contains regional taxa at the eastern margin of their range, outliers of some wetter forest taxa, and some found only in the eastern part of the region.

The close by Porongurup (Locality 104) was, compared to its neighbours, also relatively diverse with seven taxa. The reason for its diversity is that it includes the Porongurup Range, an outlier of high rainfall that included two sites with intermediate point diversity. Site 116 had six taxa and Site 117 had four, all of which were found at Site 116. Considerable WAM material contributed only one other taxon. The locality was slightly more diverse than the most diverse of the eastern localities, such as Qualeup (Locality 73) or Darkan (Locality 54), but had very different taxa. The taxa were more characteristic of wet forest localities, and also quite different from those in the more diverse adjacent localities of Stirling Range (Supplementary Locality 201) and Two Peoples Bay (Locality 113)

There were some localities of high diversity in high rainfall jarrah forest but these were not as rich as the Mundanng (Locality 22), Kelmscott (Locality 26) or Beraking (Locality 27) further north or any of the main karri forest localities. The localities of Balingup (Locality 69) and Wilga (Locality 61) both recorded eight taxa. These reflected the contribution of sites of high point diversity shown in Figure 5.2. Sites 104 and 92, which were found in the Ballingup and Wilga localities respectively, both had seven taxa, the highest point diversity in the Jarrah forest of any sites in the jarrah forest. The adjacent locality of Bridgetown (Locality 70) had seven taxa all found at Site 100. The locality with the highest diversity in the jarrah forest was just to the north of the Ballingup, Wilga and Bridgetown localities in the locality of Burekup (Locality 51). Unlike the three other diverse Jarrah forest localities, the local diversity of nine found in Burekup was the result of two intermediate richness sites (Sites 12 & 13), both with five taxa, supplemented by WAM material.

In general, point diversity was more similar to locality diversity in wetter areas of the jarrah forest than in either the northern Jarrah Forest or much of the Warren Bioregion. As well as the contribution of Sites 92, 100 and 104 to the diversity of localities Wilga, Bridgetown and Ballingup, this is further illustrated by the fact that the high intermediate point diversity of Site 11 contributed all six taxa to the Dwellingup (Locality 35) locality. Throughout the jarrah forest, both point diversity and local diversity were extremely variable. The region is characterised by many sites of intermediate and low richness and reflected strongly in both Figures 5.1 and 5.2.

Locality diversity in the north of the region, an area receiving less than 800 mm annual rainfall, reflects the distribution of many sites of low, low-intermediate or sometimes zero point diversity. Coastal localities Yanchep (Locality 17) and Walyengarra (Locality 6) were the most diverse, with eight and six taxa respectively. The Yanchep locality is notable in that it contained Site 46, the site with the highest point diversity (6 taxa)

recorded on the Swan Coastal Plain. In fact, other than some coastal localities, much of the northern Swan Coastal Plain Bioregion and extreme northern part of the Jarrah Forest Bioregion is comprised of localities with between zero and three taxa. The Chittering locality (Locality 15) is a notable exception in that it had a local diversity of ten. This locality includes Site 57 (Mount Byroomanning), the only site in the north of the region with high point diversity (7 taxa).

Local diversity drops quickly on the eastern margin of the Jarrah Forest Bioregion congruent with rainfall. Localities on the eastern margin of the jarrah forest have many fewer taxa than the adjacent richer localities of Mundaring (Locality 22), Kelmscott (Locality 26) and Beraking (Locality 27). However, Dewars Pool (Locality 16), Mount Observation (Locality 24) and Luptons (Locality 32) have seven or eight taxa, a diversity similar to some wetter localities in the jarrah forest. The richness of these eastern localities is partly representative of the presence of remnant jarrah/wandoo woodlands, forming some large conservation parks. In much of the central eastern part of the region, there are many localities with no taxa. This is a reflection of the amount of cleared farmland in this part of the region. However, there are three localities that stand out. Darkan (Locality 54), Qualeup (Locality 73) and Uannup (Locality 84) have local diversities of six, five and six taxa respectively. They are surrounded by localities with diversities of one or two taxa. The diversity of these three localities is the result of high-intermediate point diversities obtained by sampling a single site during this study. These sites sometimes represent the only significant conservation areas in these localities. These results indicate the important contribution that conserved remnant vegetation makes to the biodiversity of such localities.

5.4.1. SUMMARY OF RELATIONSHIP BETWEEN POINT AND LOCALITY DIVERSITY

In some cases point diversity and local diversity are similar. In others, point diversity and aggregate point diversity are considerably less than local diversity. The relationship between aggregate point diversity (calculated from data collected during this study) and local diversity (data from all sources) is illustrated in Figure 5.5. The figure includes a map showing localities where local diversity was greater than three, and fifty percent or more higher than aggregate point diversity. These localities are principally in the north of the region, and in the central Warren Bioregion, but there are outliers in the both the east and west. The Perth (Locality 21), Fremantle (Locality 25) and Wellard (Locality 29) localities were not sampled as part of this study and, consequently, had no measure of aggregate point diversity. The Kelmscott (Locality 26) locality, which is notable in Figure 5.5, has already been shown to have very high aggregate point diversity in Figure 5.3. Other than the taxa represented in point diversity, and consequently collected during this study, only two additional taxa were recorded from this locality.

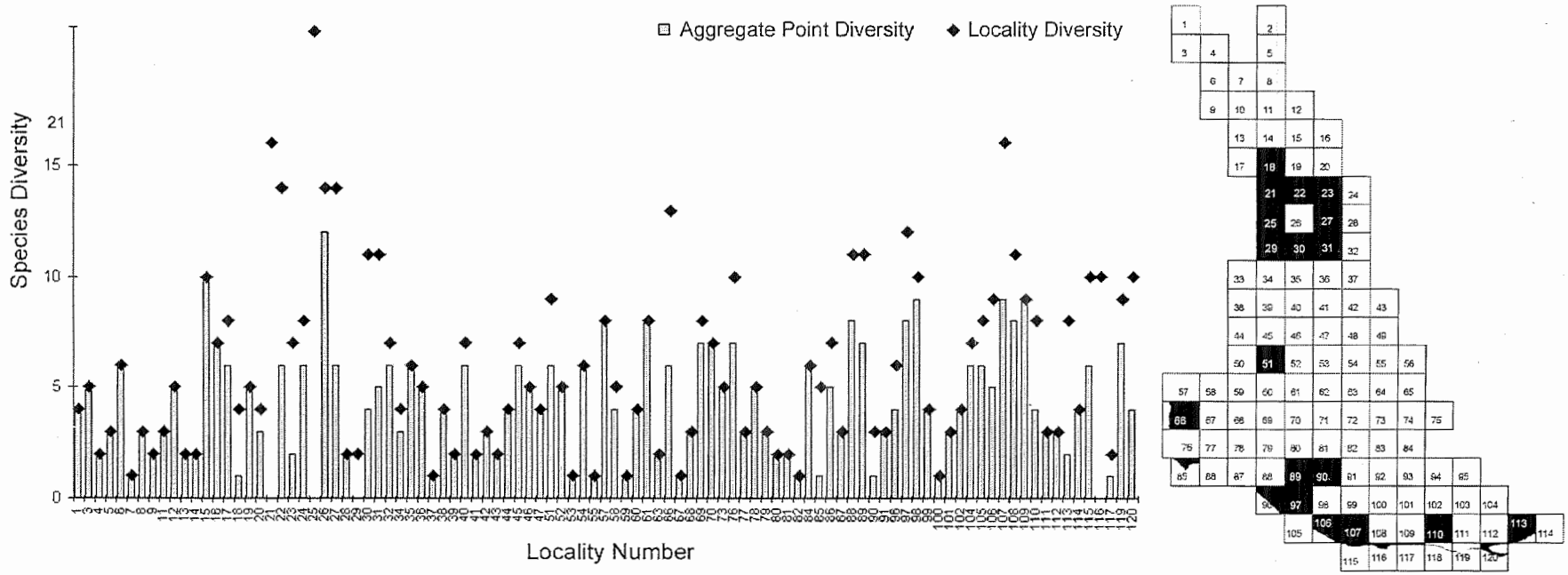


Figure 5.5. Localities showing aggregate point diversity from Table 5.2 and local diversity from Figure 5.4. Localities from which no taxa were recorded were excluded. Aggregate point diversity is the total number of taxa collected from one or more sites sampled during this study and locality diversity is the total number of taxa recorded from that locality by data from all sources. The map shows a schematic representation of the twenty-four localities, shown in black which had a local diversity of greater than three and in which local diversity was 50% or more greater than aggregate point diversity.

The Burekup locality (Locality 51), containing relatively high rainfall jarrah forest, was significant in that it was the only one within the central part of jarrah forest where local diversity was much higher than aggregate point diversity This locality had the lowest microhabitat differentiation of the ten localities illustrated in Figure 5.3. This suggests that although three sites were sampled within this locality, they were still not enough to account for the change in species composition within this part of the jarrah forest.

With the exception of those localities not sampled during this study, the findings here suggest that the sites sampled did not represent the full range of taxa within each locality unit. Within the black areas shown on the map in Figure 5 5, there is considerable change in terrestrial isopod communities within short distances across the landscape Changes at such a scale are likely to be the results of small scale environmental influences rather than broad scale factors such as climate. This was recognised by Whittaker et al (2001) who suggested that small scale spatial variation in the distribution of organisms is likely to be due to signal from environmental factors measurable at the small scale. In this case, these factors are undoubtedly related to the provision of microhabitats and their properties. An alternative explanation of high local diversity would be due to a disproportionately high sampling effort in these localities. This is not the case, particularly as the two most diverse localities were not sampled at all during this study. This issue of sampling effort will be addressed in Section 5.6.

5.5. LANDSCAPE DIVERSITY

The purpose of the next chapter is to define meaningful landscape units in terms of terrestrial isopods In the meantime, this section undertakes a brief analysis of diversity at a broader scale in order to examine the relationship between inventory diversity at the local and landscape scales, and to assess landscape differentiation diversity. Composite landscape units of approximately equal area were described in Table 2.2 in Section 2.2. Figure 5.6 shows a schematic plot of landscape diversity, in a similar manner to Figure 5.4, and key to the landscape unit (LU) numbers. Table 5.3 shows landscape diversity, landscape differentiation and their contributing localities and locality diversities.

Not surprisingly, Perth (LU 5), which contained the diverse localities of Perth (Locality 21, 16 taxa) and Fremantle (Locality 25, 21 taxa), was the most diverse landscape unit with twenty-five taxa. Since there were twenty-one taxa in the Fremantle locality and there are twenty-five in the Perth LU, there were four taxa not found in the richest locality of Fremantle that occurred near to it. Therefore, the landscape scale clearly reinforces the diversity of this part of the region. The high diversity is probably due to the presence of a wide variety of landforms, including the Swan River and the Darling Scarp, and consequently, a high turnover of species within the landscape.

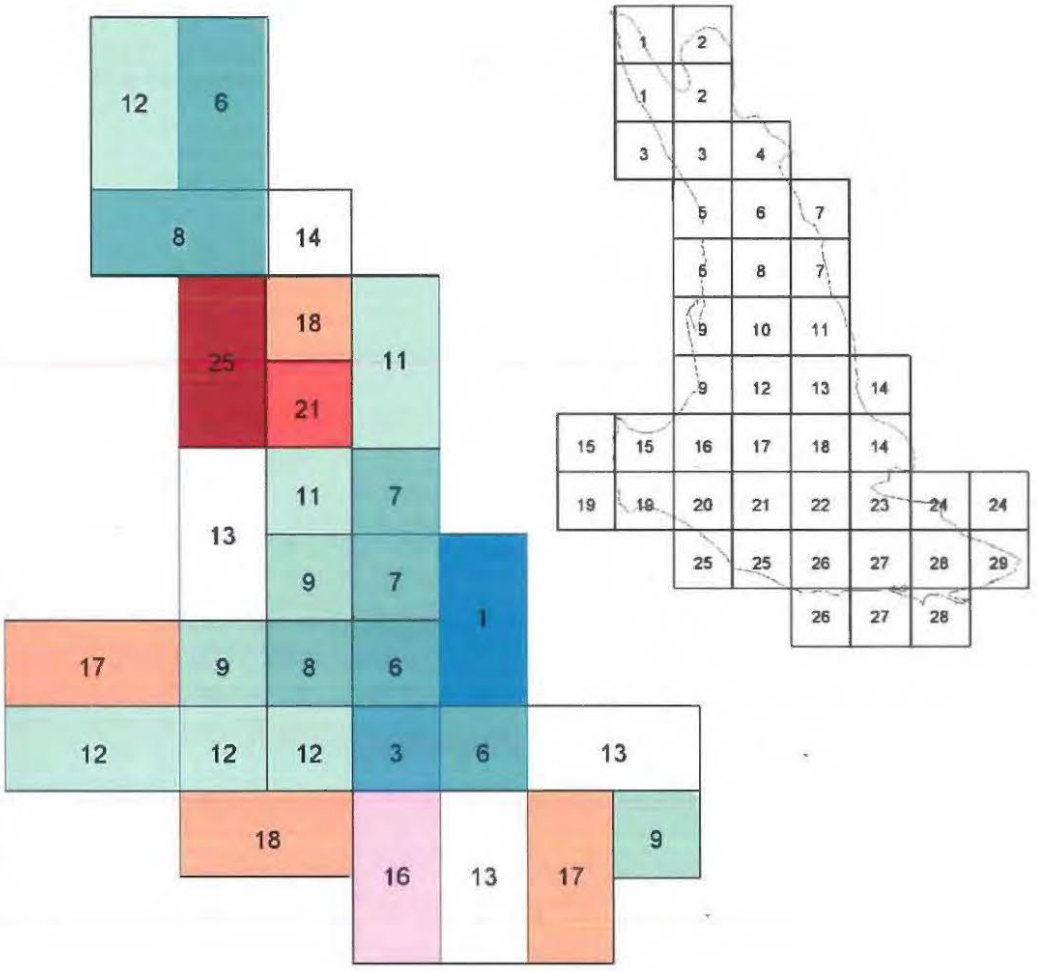


Figure 5.6. Landscape diversity measured by the species richness of landscape units derived from the equitable grouping of localities. Inset is a key to the landscape unit numbers used in Table 5.3 and in the text. The colour scheme, showing the most diverse areas in red and the least diverse in blue, is the same as that in Figure 5.4.

The landscape scale also reinforces the dramatic drop in diversity in the northern part of the Swan Coastal Plain. There were only six taxa recorded from Dandaragan (LU 2) and eight from Gingin (LU 3). This is a reflection of both low point diversity and low local diversity. At the very far north of the region, Hill River (LU 1), which contains Mount Lesueur, a significant geomorphological feature and a locality of high plant diversity (Hopkins et al, 1983), recorded twice as many taxa as Dandaragan (LU 2), with twelve taxa and a third more than Gingin (LU 3).

Table 5.3

Local diversity, landscape diversity and landscape differentiation. Local diversity and the localities were shown in Figure 5.4 and landscape diversity and the location of the landscape units is shown Figure 5.6.

Landscape Unit	Number of landscape sub-unit (Locality)								Local diversity								Mean Local diversity	Landscape diversity	Landscape differentiation
	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8			
1	1	3	4	6	9	202			4	5	2	4	2	6			3.83	12	3.13
2	2	5	7	8					0	3	1	3					1.75	6	3.43
3	9	10	11	13	14				2	0	3	2	2				1.80	8	4.44
4	12	15	16						5	10	7						7.33	14	1.91
5	17	18	21	25	29	200			8	4	16	21	2	3			9.00	25	2.78
6	19	20	22	23					5	4	14	7					7.50	18	2.40
7	24	28	32						8	2	7						5.67	11	1.94
8	26	27	30	31					14	14	11	11					12.50	21	1.68
9	33	34	38	39	44	45	50	51	0	4	4	2	4	7	0	9	3.75	13	3.47
10	35	36	40	41					6	5	7	2					5.00	11	2.20
11	37	42	43						1	3	2						2.00	7	3.50
12	46	47	52	53					5	4	5	1					3.75	9	2.40
13	48	49	54	55					0	0	6	1					1.75	7	4.00
14	56	65	74	75					0	1	0	0					0.25	1	4.00
15	57	58	66	67					8	5	13	1					6.75	17	2.52
16	59	60	68	69					1	4	3	8					4.00	9	2.25
17	61	62	70	71					8	0	7	0					3.75	8	2.13
18	63	64	72	73					2	0	0	5					1.75	6	3.43
19	76	77	85	86					10	3	5	7					6.25	12	1.92
20	78	79	87	88					5	3	3	11					5.50	12	2.18
21	80	81	89	90					2	2	11	3					4.50	12	2.67
22	82	83	91	92					1	0	3	0					1.00	3	3.00
23	84	93	94						6	0	0						2.00	6	3.00
24	95	201							0	13							6.50	13	2.00
25	96	97	98	105	106				6	12	10	8	9				9.00	18	2.00
26	99	100	107	108	115	116			4	1	16	11	10	10			8.67	16	1.85
27	101	102	109	110	117	118			3	4	9	8	2	0			4.33	13	3.00
28	103	104	111	112	119	120			0	7	3	3	9	10			5.33	17	3.19
29	113	114							8	4							6.00	9	1.50

This broader scale analysis provides a clearer summary for the northern part of the region, because the variability in the point and locality scale analyses is reduced, and a clearer pattern emerges. Richness declines both eastward and northward from the high richness of the Perth area. East of Perth (LU 5), Wooroloo (LU 6) and Jarrahdale (LU 8) have landscape diversities of eighteen and twenty-one taxa respectively. Even LUs at the north-eastern margins of the Jarrah Forest Bioregion have relatively high diversity. Chittering (LU 4), which includes the diverse Chittering (Locality 15) locality and Site 57, the richest site in the northern part of the region, has fourteen taxa. Northam (LU 7) which has eleven taxa, is comparable to Dwellingup (LU 10) and more diverse than Collie (LU 12), Donnybrook (LU 16), or Bridgetown (LU 17) which all contain localities of high rainfall jarrah forest.

Landscape units in lower rainfall areas on the eastern margin of the jarrah forest typically have six or seven taxa. Crossman (LU 11), Darkan (LU 13), Dinninup (LU 18) and Frankland (LU 23) show a consistent pattern of diversity that was not evident at either of the two smaller scales.

In the south of the region, the most diverse landscape units are those receiving the most rainfall. The four richest LUs, Northcliffe (LU 25), Deep River (LU 26), Demark (LU 27),

and Albany (LU 28), are consistent with the main distribution of karri forest Northcliffe includes the diverse Northcliffe (Locality 97) and Shannon (Locality 98) localities and is the most diverse in the south with eighteen taxa. While it is not as diverse as Perth (LU 5), it has identical diversity to Wooroloo (LU 6). The adjacent Deep River (LU 26) also has relatively high diversity with sixteen taxa Both Busselton (LU 15) and Albany (LU 28) recorded seventeen taxa, only one less than the high rainfall Northcliffe (LU 25). Both these receive about 1000 mm annual rainfall per year and are coastal, contain landform diversity and have both jarrah and outlying karri forest. Landscape diversity richness in the Albany LU is boosted by the presence of the Porongurup Range which contains all but two of the regional taxa and outliers of the wetter forest dwelling species.

The nearby Tambellup LU (LU 24) is dominated by the Stirling Range (Supplementary Locality 201), which is, in essence, a landscape unit of its own. It has all the regionally distributed taxa and all the forest taxa except the two log-dwelling Acanthodillo. Its diversity is remarkable, apart from the Stirling Range the other locality within it, Tenterden (Locality 95), recorded no taxa all. The thirteen taxa present at the Stirling Range is more than most forested landscapes and again highlights the influence of landform variation upon taxa diversity at all scales

A dramatic drop in landscape diversity in the southern part of the region congruent with decreasing rainfall is reflected in the diversities of the Donnelly (LU 20) and Manjimup (LU 21) LUs. Both have a diversity of twelve taxa, a third less than the adjacent Northcliffe LU. Nearly all the diversity of both of these LUs comes from single karri forest localities with eleven taxa, namely the Charnwood and Pemberton localities respectively

5.5.1. SUMMARY OF RELATIONSHIP BETWEEN LANDSCAPE DIVERSITY AND LANDSCAPE DIFFERENTIATION

The relationship between landscape diversity and landscape differentiation is shown in Figure 5 7. Eight landscape units, Dandaragan (LU 2), Gingin (LU 3), Crossman (LU 11), Kojonup (LU 14), Darkan (LU 13), Dinninup (LU 18), Tonebridge (LU 22) and Frankland (LU 23), displayed low landscape diversity but high landscape differentiation. All of these except the Crossman LU, contained a locality with zero locality diversity (Table 4.3). With the exception of Gingin, the LU with the highest landscape differentiation, all were in the eastern part of the Jarrah Forest Bioregion or in the north of the Swan Coastal Plain (Dandaragan)

The Darkan LU has high landscape differentiation (4.00) because of the presence of high locality diversity of the Darkan locality (Locality 54) highlighted in the previous section. The Darkan locality had a local diversity of six taxa while the other three localities contributing to the Darkan LU had only one taxon between them. Other LUs in this group had high landscape differentiation due mainly to low landscape diversity with many parts of the landscape having been cleared of native vegetation, resulting in localities without suitable areas for sampling and hence no taxa

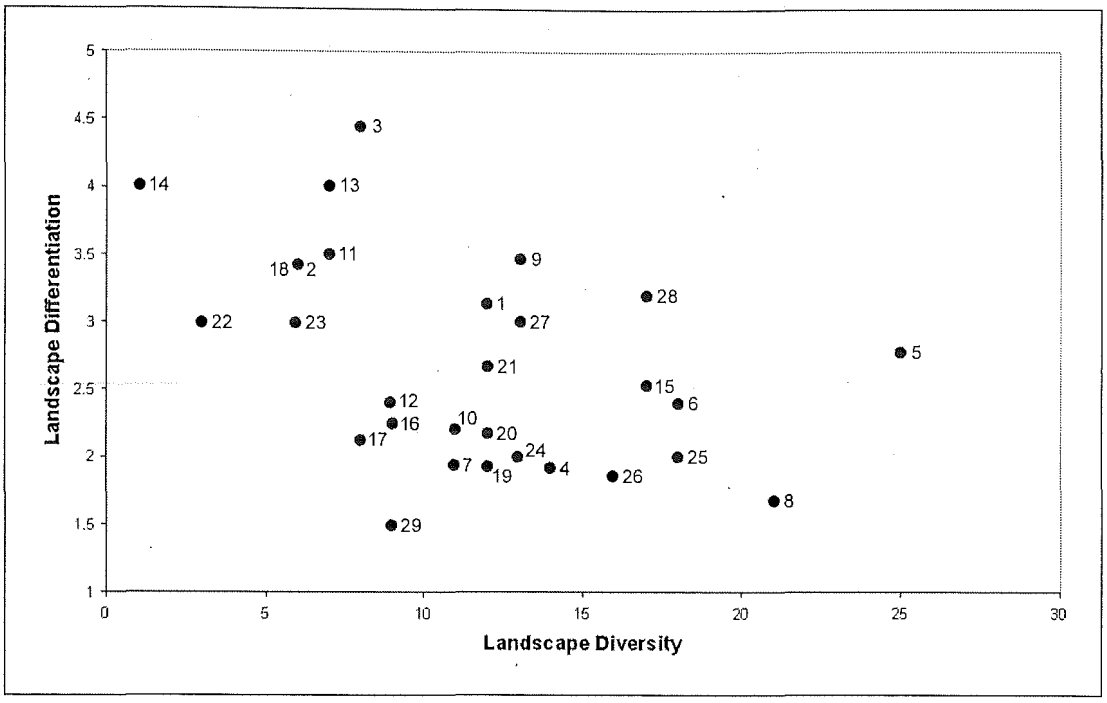


Figure 5.7. Each of the twenty-nine landscape units plotted showing landscape diversity landscape differentiation. The number of the landscape unit is shown next to each point. Note that Landscape units 2 and 18 have identical data.

Of the remaining group of LUs Bunbury (LU 9) had the highest landscape diversity. The LU included the diverse locality of Burekup (Locality 51) with nine taxa and also parts of the southern Swan Coastal Plain, some with no taxa. The landscape diversity in the southern part of the Swan Coastal Plain may be underestimated due to lack of sampling, an issue discussed in the next chapter.

The richest landscape units of Perth (LU 5) and Jarrahdale (LU 8) had quite different landscape differentiation. Perth, comprised of localities in the Swan Coastal Plain Bioregion, was much higher than that of Jarrahdale, which is comprised of localities in the Jarrah Forest Bioregion. This may be a reflection of the greater diversity of landforms, as mentioned in the previous section, and the association of taxa with them demonstrated in Northern Patterns (Section 4.7) in the previous chapter. Both LUs in the far north and the far southeast had high landscape diversity. This too may be related to prominent geomorphological features. Hill River (LU 1) and Albany (LU 28) both with relatively high landscape differentiation included Mount Lesueur and the Porongurup range respectively.

There are no discernible patterns amongst the remaining LUs. Landscape differentiation does not appear to be related to the landscape diversity, in fact apart from the LUs discussed, landscape differentiation was quite similar. This is most evident in the four landscape units comprising the wetter part of the Jarrah Forest Bioregion, Dwellingup (LU 10), Collie (LU 12), Donnybrook (Lu 16) and Bridgetown (LU 17). All had similar landscape diversities and landscape differentiation (Figure 5.6) despite contrasting contributing locality diversities (Table 5.3).

Overall, an examination at the landscape scale provided some very clear boundaries in patterns of diversity. There were well defined areas of high broad-scale inventory diversity in the north and the south of the region. However, some of the boundaries were more clearly seen at the locality scale, because the landscape scale masked some of the important smaller scale changes, particularly in the central Warren Bioregion. The preceding patterns of diversity should however be seen as preliminary because neither area nor sampling effort was strictly controlled at either the locality or landscape scale. Clearer patterns would be derived from such an approach. However, the patterns provide an excellent foundation from which to compare the biogeographical patterns of the previous chapter, and upon which to build a biogeographical model in the next chapter. Before this can proceed, it has to be established whether these patterns of biogeography and diversity are genuine or artefactual, the result of geographical or methodological biases in the collection and acquisition of the data. This is the purpose of the next section. Because landscape units are larger in area than localities, they contain more data per geographical unit, and, to avoid units with no data, much of the investigation into the nature of the data was made at this scale.

5.6. THE INFLUENCE OF THE DATA

5.6.1. THE GEOGRAPHY OF SAMPLING

The fundamental question relating to the reliability of the data is whether species richness patterns, and consequently the distributions of the contributing species are genuine or a result of more collecting effort in some localities. Figure 5.8 shows the patterns of locality and landscape diversity shown in Figures 5.4 and 5.6 along with the number of records from which these patterns were generated. A record was defined in the glossary (Table 2.4 in Section 2.9).

The number of records is only partial representation of sampling effort because it cannot be determined from the WAM material where sampling occurred but no species were found. In addition, much of the WAM material may have resulted from studies where terrestrial isopods were not the target organism. Nevertheless, an examination of the relationship between the patterns of diversity and the records allows insight into the potential artefactual nature of the patterns.

On initial viewing, there appear to be some obvious relationships. This is expected to some degree because the number of taxa and the number of records are not independent. While there appears to be a direct relationship between the number of taxa and the number of records, there are some quite subtle and often informative exceptions.

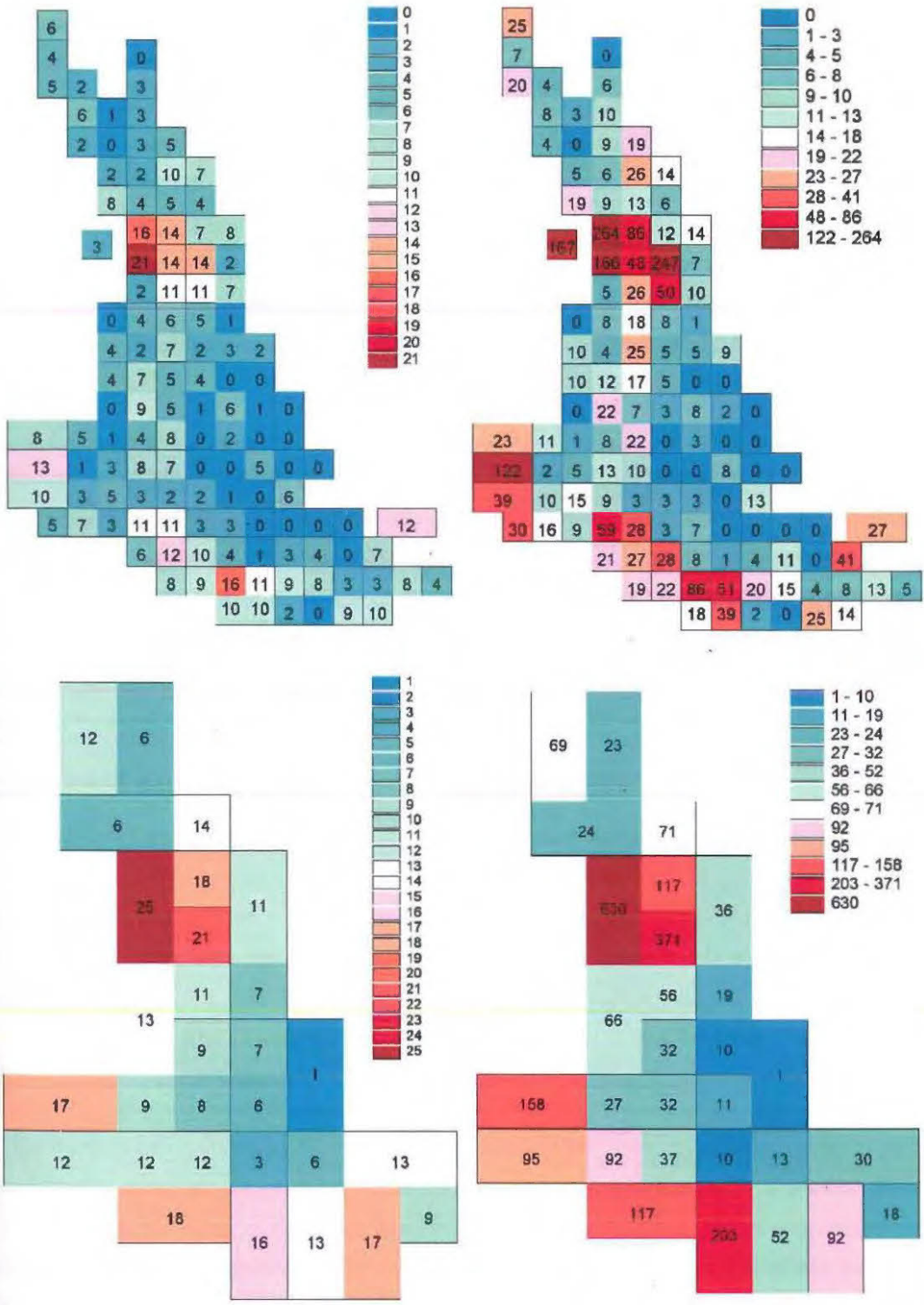


Figure 5.8. The schematic patterns of local (upper left) and landscape (lower left) diversity shown next to the number of records for the geographical unit (upper and lower right) from which they were generated. A similar colour classification scheme has been applied to all four maps.

With 264 records, the Perth locality (Locality 21) had the most for any locality. Despite this, it has five less taxa than Fremantle (Locality 25), which has only 166 records. The adjacent localities of Mundaring (Locality 22), Kelmscott (Locality 26), and Beraking (Locality 27) all have fourteen taxa but vastly differing numbers of records (86, 48 and 247 respectively). It seems that despite the potentially greater sampling effort in the Mundaring and Kelmscott localities, no additional taxa were recorded. The Kelmscott locality was notable in Figure 5.5 in that twelve of its fourteen taxa were accounted for by three samples of point diversity. A similar pattern was demonstrated by the Jarrahdale and Yaganing (Locality 31) localities. Both recorded eleven taxa but Yaganing had twice as many records as Jarrahdale (Locality 30). The data for the Perth and neighbouring localities suggest that the sampling has adequately represented the number of taxa found there.

There are generally far fewer records for the south of the region. However, the number of records for some localities (e.g. Cowaramup Locality 66, Charnwood Locality 88 and Deep River Locality 107) approaches that of localities described in the previous paragraph. While the localities with high inventory diversity, such as Cowaramup and Deep River, have higher numbers of records, this is not always the case. Charnwood and Pemberton both had eleven taxa but Charnwood had 59 records, twice as many as Pemberton. Cowaramup had thirteen taxa while the adjacent Karridale (Locality 76) locality had only three fewer taxa from a third of the records.

5.6.2. CASE STUDY OF HIGH RICHNESS AND MANY RECORDS

The following section looks at some of the most diverse landscape units (LU) identified in Section 5.5 and examines whether these have been the subject of disproportionately high sampling effort and, if so, whether this has influenced their diversity. The Perth LU (LU5), the most diverse, also had the most records (630). Jarrahdale (LU 8) to the east, the second most diverse, had the second highest number of records with 371. Wooroloo (LU 6), next to Perth and Jarrahdale, and Northcliffe (LU 25) in the far south had the equal third highest records with 117.

The Perth (LU5), Wooroloo (LU 6) and Jarrahdale (LU8) landscape units were, in part, included in a recent survey of nineteen urban bushland remnants in the greater Perth area. These remnants of native vegetation, effectively islands in a sea of urbanisation or landscapes heavily modified for agriculture, were extensively sampled by pitfall trapping. The methods of the study were given by How et al. (1996) and Harvey et al. (1997) and material was lodged in the WAM. Therefore, it makes a contribution to the data analysed here (see also Section 4.7). A summary of the number of records, including the contribution of the urban bushland collection (UBC), and the numbers of taxa can be seen in Table 5.4.

Table 5.4.
The contribution of the urban bushland collection (UBC) to the records and richness of landscape units in the Perth area.

Landscape Unit	Number of Sites in UBC	Number of Records		Number of Taxa	Taxa in UBC	
		All Sources	UBC	All sources	Total	Unique
Perth	13	630	328 (52%)	25	15 (60%)	1
Wooroloo	3	117	46 (39%)	18	8 (44%)	1
Jarrahdale	3	371	29 (8%)	21	8 (38%)	1
Total	19	1118	403 (36%)	33	17 (52%)	0

Overall, the UBC contributed 403, or 36%, of the records for the three landscape units. The influence was most apparent in the Perth LU (LU 5) where the study accounted for 52% of the records. As a whole, the study did not produce any taxa that were not already represented in the Museum collection or were not collected during this study. The study collected only 60 % of the taxa in the Perth LU where there were 13 sites, 44% of the taxa in Wooroloo (LU 6) where there were three sites and 36% of the taxa in Jarrahdale (LU 8) where there were also three sites. In each of the three LUs, the UBC accounted for only one taxon that would otherwise not have been recorded there.

From the observations it is clear that over a third of the records for some of the richest LUs contributed no additional taxa at the landscape scale. There are, however, two principal benefits of a intensive study of this type. Firstly, it provides for much more material than otherwise would have been collected. This allows for a better assessment of taxonomic characters at both the point inventory scale (within samples), and over the geographical range of the organism in question. In addition, both male and female specimens are usually present, and in some cases ontogenetic series have been collected. This allows for a much more reliable determination of taxa. Secondly, such a large-scale study allows for a much clearer determination of the distributional range of the species present. This was evident in Northern Patterns (Section 4.7) in the previous chapter. However, UBC records are limited in their application, because, being collected from pitfall traps, none of them has microhabitat data.

The nature of the urban bushland study has also inflated the number of records for the three relevant LUs. There are a number of reasons for this. Firstly, each of the nineteen remnants was sub-sampled by a number of pitfall trap lines. These were designed to reflect, where possible, changes in the vegetation types in the various remnants. While sometimes only a few metres apart, these separate trap lines increase the nineteen remnants to fifty-two geographical data points, each one effectively contributing a different site (see Glossary Section 2.9 for site definition). This greatly increased the number of records for common, widely distributed and mobile taxa. These extra records

are of little value since there is no microhabitat data. Secondly, the pitfall traps were emptied seasonally. This constituted a different sampling date and therefore a new record, thereby duplicating records. Since pitfall traps were installed for up to six months, this additional data are also of little value.

The degree to which sub-sampling and seasonal replication have influenced the data is illustrated by the fact that, without seasonal replication the 403 records from the UBC would have been 186. Without internal sub-sampling with seasonal replication the number of records would have been 255, and, without [illegible] number of records would have been a mere 97. The UBC never collected more than [illegible] the taxa found in any one of the landscape units and, overall, did not collect any taxa that would not have been otherwise present. Clearly, the diversity of the area in question is not an artefact of the collecting effort during this study. It has, however, added to the clarity of some of the biogeographical patterns of the previous chapter and may, therefore, have influenced patterns of diversity at smaller scales.

The richness of the greater Perth area is remarkable. This is perhaps not due to the amount of collecting but may be related to its continuity through time. Understandably, many of the older records come from Perth (Locality 21), Fremantle (Locality 25) and adjacent localities. The landforms and vegetation of these localities are now highly modified. The number of records for these localities is also exaggerated because much of the early material was registered as individual specimens. In early records, a jar containing twenty terrestrial isopods would have constituted twenty registration numbers and therefore, as each was examined individually, twenty records in this study. In later records a jar containing 20 specimens of the same species would have one registration number and would constitute one record. Nevertheless, the identification of each individual had to be confirmed. Much of the older material in the Museum collection collected by Nicholls and co-workers (see Section 3.2.2) has inflated the number of records for Perth (LU 5) and Deep River (LU 6) landscape units.

The richness of the Perth LU (LU 5) is even more remarkable, given that only two sites within it were sampled as part of this study, namely, Site 46 which had a point diversity of six taxa, and Site 37, a site characteristic of many sites on the northern Swan Coastal Plain with a point diversity of one taxon. In contrast, Wooroloo (LU 6) and Jarrahdale (LU 8) were well sampled during this study. Wooroloo had seven sites, from which ten of its eighteen taxa were collected, and Jarrahdale had eight sites from which thirteen of the twenty-one taxa were present. This again illustrates the high landscape differentiation of the richest part of the region.

Since only 60% of the taxa in the Perth LU (LU 5) were represented in the UBC, the remaining 40% or 10 taxa have been collected on an ad hoc basis. Probably the most significant feature of the history of collection in the district is that all the different landforms are represented and sampling has adequately represented the vast array of potential habitats, past and present, within the landscape. It should also be noted that all

eleven introduced, littoral and secondarily aquatic taxa, occur in the Perth LU as well. This results in a taxa richness of 36, just over half of those described in Chapter 3 and approximately the same number found in the United Kingdom (Hopkin, 1991).

A similar situation in terms of the nature of records is found in the Busselton (LU 15) LU. It had seventeen taxa and 158 records. It was the equal fifth highest richest LU and had the fourth highest number of records. Eighty-seven (55%) of the records came from the "Glenbourne Study". This study used pitfall traps to sample six sites, in differing vegetation types in a woodland block in the Cowaramup locality (Locality 66), nine times in thirty months. When seasonal replication is eliminated, but individual sites are retained, the 87 records are reduced to 21. Including only 21 records, instead of 87, the total for the Busselton LU (LU 15) would make the total number of records only 92. This is three less than adjacent Leeuwin LU (LU 19) and identical to the Donnelly (LU 20) LU which both had three less taxa. Furthermore, the Glenbourne Study collected only five of the seveteen taxa found in the Busselton LU and none were unique. Additional records, generated by pitfall trapping in species rich localities, do not add new taxa. What does generate more taxa is a collecting strategy that encompasses landscape differentiation.

This subsection and previous sections have shown that at the broad scale, landscapes with high diversity have a lot of records and not the other way round. These are also landscapes in which terrestrial isopods species composition changes rapidly over small spatial scales. The presence of microhabitat was an important contributing factor to considerable differences in point diversity. The distributions in Chapter 4 often showed that within the range of many species there are often more "holes" than "objects". This may be due to the existence of areas of suboptimal or unsuitable habitat and temporal environmental variability (see Section 4.1) but can also be influenced by collecting methodology. Critical to the understanding of the nature of "holes" and "objects" is a satisfactory sampling method. This is even more important when the target organism shows high differentiation diversity at a range of spatial scales. If the sampling method is not effective, and the target organism does not have an equal chance of being sampled throughout its geographical range, the resulting distributional pattern will be one of artefactual "holes". In other words, species distributions will contain holes where objects should have been and ranges may appear smaller than they actually are. The following section examines the dataset for the degree to which the taxa are represented by the different collection techniques. Of particular importance is that the collection methods employed in the stratified collection undertaken during this study were effective in representing the terrestrial isopods of south-western Australia.

5.6.3. THE EFFICACY OF THE COLLECTION METHOD

The exaggeration of the number of records by pitfall trapping and its relative lack of efficacy, suggests that it might be pertinent to examine the influence of collecting method upon the taxa richness. If this was not an effective way of collecting terrestrial isopods, how should collecting effort be best applied? In this study, terrestrial isopods alone were

targeted and collected by hand with the addition of Berlese funnel extraction. The validity of the patterns of point diversity (Figure 5.1 & 5.2) will depend upon the efficacy of these methods. The contribution to the dataset of this study in relation to the WAM collection and the UBC is shown in Table 5.5. This study contributed nearly half (47%) of the overall records but, considering all of these records have reliable and standardised microhabitat data, its contribution to the regional biogeography is much greater. This is emphasised further by the numerically exaggerated nature of the both the UBC and elements of the rest of the WAM collection.

Table 5.5
The three sources of data, the Western Australian Museum general collection (WAM), the Urban Bushland Collection (UBC) and the present study, used for analysis in Chapter 4 and 5 and the number of taxa represented in each.

Source of Records	Collection Approach	Records	Indigenous Taxa	
		n (%)	Total (%)	Unique to subset
This Study	Targeted	1184 (47%)	51 (85%)	11 (18%)
WAM	Targeted or Non-specific	925 (37%)	49 (82%	7 (12%)
UBC	Non-specific	403 (17%)	17 (28%)	0 (0%)
Total		2512	60	18 (30%)

Both this study (85%) and the museum collection (82%) represented most of the taxa. Overall, the UBC, which was confined to only a part of the region, accounted for 28% of all the taxa. This is quite high, considering its limited geographical extent, but not surprising since it sampled an area of very high richness. However, as was shown in Table 5.4, in the Perth LU, the principal area of the study, it accounted for only fifteen of the twenty-five taxa.

Nine indigenous mainland taxa (15%) occurring in the region were not collected during the stratified collection of the present study. At first, this seems to be quite a high proportion. Seven of these taxa were represented in the WAM and two, Philosciidae species 1 and Acanthodillo flavus, were present in both the WAM and UBC collections. The characteristics of these taxa are presented in Table 5.6. Four of the nine taxa are known only from a single locality, two of which are probably associated with high rainfall and two are very old records. Two were from the far south east of the region, one probably occurs outside the region and the other two are probably cryptic, being known only from pitfall traps.

The two locally distributed taxa from the coastal part of south east of region, Buddelundia species 8 and Cubaris species 4 were found in the Albany LU (LU 24). This has high landscape diversity (Figure 5.6) and it is probable that the number of sites sampled in this LU during this study was not adequate to cover comprehensively the variety of habitats in this area.

Table 5.6.
Characteristics of species not collected during the present study. The patterns are those described in Chapter 4; the distributional scales are Single Locality (SL), Local, and Sub-regional (SR).

Taxon	Pattern	Scale	Description of Record(s)
Platyarthridae species 2	Single Locality	SL	A very old record without data
Philosciidae species 1	Northern	LO	Where stated, collected only from pitfall traps
Pseudoleurola new species 2	High Rainfall	SL	Known only from two adjacent sites in high rainfall karri forest
Acanthodillo flavus	Unclear	SR	Probably largely subterranean
Acanthodillo species 3	Single Locality	SL	Known from only 1 locality in high rainfall jarrah forest
Cubaris species 4	South Eastern	LO	Coastal species
Buddelundia species 1	Single Locality	SL	Very old record with questionable data from a single locality
Buddelundia species 2	Eastern	LO	Probably occurring outside of the study area
Buddelundia species 8	South Eastern	LO	Coastal species and where stated, collected only from pitfall traps

The sub-regionally distributed Acanthodillo flavus was the most widely distributed taxon not collected by this study and appears to be a cryptic species. It was collected mostly from pitfall traps in both the WAM and UBC material but was also found under rocks and logs. Also represented in both the WAM and UBC was the locally distributed Philosciidae species 1. There are no microhabitat data about this species since all material came from pitfall traps. This species is the smallest of all the Philosciidae and the only one with a densely setose dorsal surface. This suggests a different microhabitat utilisation than the regionally distributed Laevophiloscia.

Table 5.7 shows the breakdown of records by the method of collection. Not surprisingly, given the contribution of the present study, most of the records were gained by hand collection. Pitfall traps contributed over a quarter of the records, but the exaggerated contribution of these records at the broad scale has already been noted. In terms of the number of records, the only other method of note was Berlese funnel extraction, mostly obtained from this study but also used by Harvey and co-workers at the WAM. The table shows both the number of taxa collected by each method and the number unique to it. Two totals are given, firstly with records with no collection data included, and secondly, with records with no collection data removed from the dataset.

Table 5.7.
Summary of the records taxa collected by different collection methods

Collection Method	Number of Records	Number of Taxa	Number of Taxa Unique to Method	
			Including Records With No Data	Excluding Records With No Data
Not Known	499 (20%)	44 (73 3%)	4 (7%)	-
Hand Collection	1199 (48%)	52 (86 7%)	10 (17%)	16 (27%)
Berlese Funnel	117 (5%)	28 (46 7%)	2 (3%)	2 (3%)
Pitfall Traps	680 (27%)	32 (53 3%)	0	2 (3%)
Bark Trap	11 (<1%)	3 (5%)	0	0
Intercept Trap	1 (<1%)	1 (1 7%)	0	0
Other	5 (<1%)	3 (5%)	0	0
TOTAL	2512	60	16	20

The influence of the present study is reflected in the fact that twenty-seven percent of taxa were collected only by hand collection. Six of these taxa were also represented by records with no data, which, in the absence of data to the contrary, could be assumed to be hand collected, either incidentally found or deliberately targeted. It is not surprising that there were no taxa collected solely by pitfall trapping. Two taxa, possibly collected solely by pitfall trapping, Buddelundia species 8 and Philosciidae species 1, may have been collected by other methods since they were present in WAM material without collection data. Berlese funnels produced two taxa not collected by other methods. Both of these, Styloniscus species 4 and Pseudodiploexochus species 3, were collected from single localities as part of the present study. These are small species and highlight the value of litter extraction in capturing taxa that can be overlooked by hand picking. Berlese funnels and, to a lesser degree, pitfall traps, are valuable in that they are less time consuming during fieldwork and they usually result in more specimens of a taxon than hand picking. More specimens are valuable in assessing the taxonomic importance of some variable character states. The disadvantage of both Berlese funnels and pitfall traps is that the results of both require many hours picking specimens from debris and unwanted taxa under a microscope. The results here suggest that, if the goal is to maximise the number of taxa collected, time is best spent targeting cryptic microhabitats such as logs rather than sorting vials. Although the resulting number of specimens is likely to be less, the number of taxa will be greater. Berlese funnels are useful where litter is too dense, too plentiful or too wet to sort effectively on site. This section suggests that ecological studies using terrestrial isopods based solely on pitfall trapping will underestimate the number of taxa present and are unlikely to accurately reflect differences between sites or treatments in small scale studies. Majer (1997) made a similar point when he suggested that pitfall traps alone will not adequately represent invertebrate communities, and that, in the case of ants, a combination of sampling techniques should be used. Melbourne (1999) concluded that, in certain circumstances, the results of pitfall trapping are just as likely to reflect changes in vegetation structure as

they are changes in the invertebrate communities themselves. This is a particularly pertinent observation if the target organisms have geographical ranges that are known to be concordant with small scale changes in vegetative or other landscape characteristics.

5.7. SUMMARY

This chapter has produced some key findings and developed some terminology that will be used in the following chapters. The key points are summarised below.

- Three scales of inventory diversity: point diversity; local diversity; and, landscape diversity, were developed and analysed. These terms will be used again and were defined in Table 5.1.
- Two scales of differentiation diversity; microhabitat differentiation and landscape differentiation were analysed. A third, geographical differentiation, will be examined in chapter 8. These were also defined in Table 5.1.
- There are at least two important centres of terrestrial isopod diversity. One in the Perth area and one in the high rainfall karri forests of the central Warren Bioregion.
- Throughout the region, high microhabitat differentiation was evident. This small-scale differentiation diversity is related to the landscape's capacity to provide suitable microhabitat, and to small scale landform variation, particularly in coastal areas.
- With the exception of some localities in the central wet Jarrah Forest Bioregion, point diversity very rarely accounted for diversity at the locality scale.
- Patterns were generally clearer at the broader, landscape scale, but the locality scale treatment provided for some more precise boundaries, particularly where landscape units covered steep rainfall gradients.
- The collection data suggest that the patterns of diversity are likely to be close to a true representation of the terrestrial isopod fauna of south-western Australia. The collection methods employed by the present study proved effective and the WAM collection served to provide, in the main, valuable additional distributional data.
- Three of the taxa not collected by this study were found once only within a single locality, two of them from wet forest areas. This suggests that there are some highly restricted taxa that await discovery and description.

In addition to the points made above, the distributional scales identified in Chapter 4 will also be used in the following chapters. These are, Regional, Subregional, Local, Restricted and Single Locality, and were defined in Table 4.1. To a lesser extent, the eight biogeographical patterns themselves will be used. Chapter 6 now uses the patterns of this, and the preceding chapter, to construct a biogeographic model.

CHAPTER 6

BIOGEOGRAPHIC MODEL

6.1. INTRODUCTION

Biogeographic models have been constructed by many different authors for many different reasons. The boundaries drawn vary according to both the taxa used and the methods employed. Models portray the geographical patterns of organisms at a range of scales. They have summarised global distribution of higher order plant taxa (e.g. Cox, 2001) and the fine-scale distribution of restricted invertebrates in discrete patches of the landscape (e.g. Main, 2000).

Sometimes, the edges of the geographical ranges of many species coincide. The mapping of the distribution of such species can identify zones in the landscape where species assemblages change. Such zones are called "faunal breaks" (Mesibov, 1994). When dealing with invertebrates with limited dispersal capabilities, these assemblage changes can occur over very short distances (Mesibov, 1999). As a result of mapping the distributions of a range of invertebrate taxa, Mesibov (1994) demonstrated a series of faunal breaks in Tasmania. The recognition of such breaks has important implications for the study of invertebrates. Where faunal breaks have been recognised, or are suspected, invertebrate sampling needs to be carefully planned so that the scale of sampling reflects accurately the distribution of taxa, particularly if there are taxa likely to be distributed over very short geographical ranges (Mesibov, 1994). Mesibov (1994, p.136) concluded that faunal breaks are "potentially rich sources of information on the historical zoogeography of Tasmania and its invertebrate fauna".

Within Australia, and for various reasons, the distributions of crustacean taxa have been delineated and biogeographical models constructed. A number of relevant and recent examples, using crustaceans or other invertebrates, are outlined below. Hansen and Richardson (2002) plotted the distributions of species of the Tasmanian endemic freshwater crayfish *Parastacoides*, many of which are local or short range endemics, and were able to highlight the importance of historical factors in determining present-day patterns within the landscape. The distribution of the genus as a whole lies almost entirely to the west of a previously recognised boundary, that of "Tyler's Line", previously summarised by Mesibov (1994). This boundary is also recognised in frogs and a range of moisture dependent invertebrates, particularly millipedes (Mesibov, 1994). The capacity of biogeographic models to explain the role that geography has played in the modes of speciation of a regional fauna is enhanced by the addition of distributional information for more taxa. This is particularly so if phylogenetic data are also considered.

Phylogenetic information was used by Whiting et al. (2000) to construct a biogeographic model of Australia freshwater crayfish. The model considered phylogenetic and distributional data for species in ten genera. Rather than constructing new biogeographical boundaries, Whiting et al. (2000) assigned conservation priorities to existing IBRA regions (IBRA was discussed in Subsection 1.5.4 and Figure 1.4). Compared to previous schemes, they found important differences in bioregional

conservation priorities when determinations were made based on crayfishes. This highlights the need for a broad taxonomic representation, particularly invertebrates, when determining conservation priorities.

Using terrestrial isopods, Sfenthourakis (1996a) constructed a biogeographic model for terrestrial isopods of the central Aegean islands, and contributed significantly to the resolution of the palaeogeographic history of the region. A comprehensive taxonomic inventory and a systematic collecting strategy, designed to represent all habitat types within geographic subdivisions, enabled Sfenthourakis (1996a) to delineate zones of faunal similarity. The analysis involved the recognition of subregions and characteristic taxa whose distributional limits were congruent with them. Both were then used to explain the origins of the fauna within the central Aegean.

Delineating zones of faunal similarity or diversity was an integral part of all examples of biogeographic models discussed above, and is essential to any biogeographical study that offers explanations as to the origins of present day patterns. To this end, and based on the data presented so far, this chapter delineates ten zones. Their boundaries are based upon the locality geographical unit, which has been a foundation of the data analysis throughout. The concordant boundaries of species distributions, along with the boundaries made apparent through the analysis of locality diversity, were used to separate the region into groups of localities containing taxa with similar biogeographies. This permitted a further analysis of the microhabitat data and, consequently, the recognition of differences in microhabitat utilisation within the zones. Having recognised zones of faunal similarity, and the types of microhabitats utilised within them, the importance of regional processes is considered in relation to each of them. This provides the foundation for a much clearer assessment of the evolution of the terrestrial isopods within the region in the final chapter of this thesis.

In order to provide a background to the model, this chapter starts by giving a short synthesis, based on the landscape units developed in the previous chapter, of the relationship between the patterns of the previous two chapters. It then describes the model and concludes with a short discussion that helps to crystallise some of the relationships between microhabitat specificity, endemism and regional richness. It illustrates the importance of surface organic matter to regional terrestrial isopods diversity, and concludes by identifying some of the factors governing the distribution of terrestrial isopods in south-western Australia.

The aims of this chapter are to:

- construct a biogeographical model for south-western Australia, based on terrestrial isopod biogeography and diversity;
- name and describe each of the zones;
- identify the distributional component of the taxa in each zone;
- identify the microhabitat utilisation in each zone; and

- identify the principal causal factors of terrestrial isopod diversity within south-western Australia.

6.2 BIOGEOGRAPHICAL PATTERNS AND DIVERSITY

6.2.1. SUMMARY OF NORTHERN LANDSCAPES

The high landscape diversity in the Perth (LU 5) and surrounding landscape units was the result of the presence of regionally and sub-regionally distributed taxa combined with many locally distributed species. Landscape diversity reflected the importance of longitudinal zonation of species related to geomorphological attributes of the Swan Coastal Plain, the influence of the coast, the Swan River, the Darling Scarp, and outlying distributions of taxa associated with the jarrah forest. There were some single locality taxa found in these landscapes, but their influence upon diversity, although important, was not as profound as in wetter forest areas. High rainfall is also less important in this part of the region. However, influence was shown by the slightly higher diversity of the Jarrahdale (LU 8) landscape unit compared to Wooroloo (LU 6) (Figure. 5.6). There is a steep rainfall gradient of some 400 mm annual rainfall between them. However, this is not as sharp as the rainfall-induced drop in landscape diversity in southern parts of the region, particularly north of the Deep River (LU 26) and Denmark (LU 27) landscape units.

6.2.2. SUMMARY OF CENTRAL FOREST LANDSCAPES

The factors influencing landscape diversity in the higher rainfall parts of the jarrah forest (e.g. Dwellingup LU 10, Collie LU 12 and Donnybrook LU 16) appear different from those of northern jarrah forest landscapes (e.g. Wooroloo LU 6 & Jarrahdale LU 8). In high rainfall jarrah forests landscapes, some regionally distributed taxa were present, some forest taxa were nearly always present, and usually one or two locally distributed or single locality taxa were present. High landscape diversity was a result of the presence of locally distributed high rainfall taxa and sometimes single locality taxa associated with leaf litter. Whereas some locally distributed taxa in northern landscapes were quite often related to landform, in wetter jarrah forest they were related to surface organic matter.

The four wetter jarrah forest LUs of Dwellingup (LU 10), Collie (LU 12), Donnybrook (LU 16) and Bridgetown (LU 17), had similar landscape diversities ranging from eight to eleven taxa. However, at the smaller scales of inventory diversity there was a great deal of variation, particularly at the point scale. The number of taxa per site within these landscape units varied between two (low point diversity) and six (high-intermediate point diversity). Clearly, site conditions influence greatly the number and composition of taxa found in this part of the region. Similar variations in the numbers of taxa per site were found in northern landscapes but this would be expected, given the greater geomorphological variation and steeper rainfall gradient. Point diversity was also lower in northern areas, despite the fact that locality and landscape diversity was higher.

Therefore, it seems that terrestrial isopod communities in central wet forested landscapes are responding to smaller scale environmental variations than communities further north.

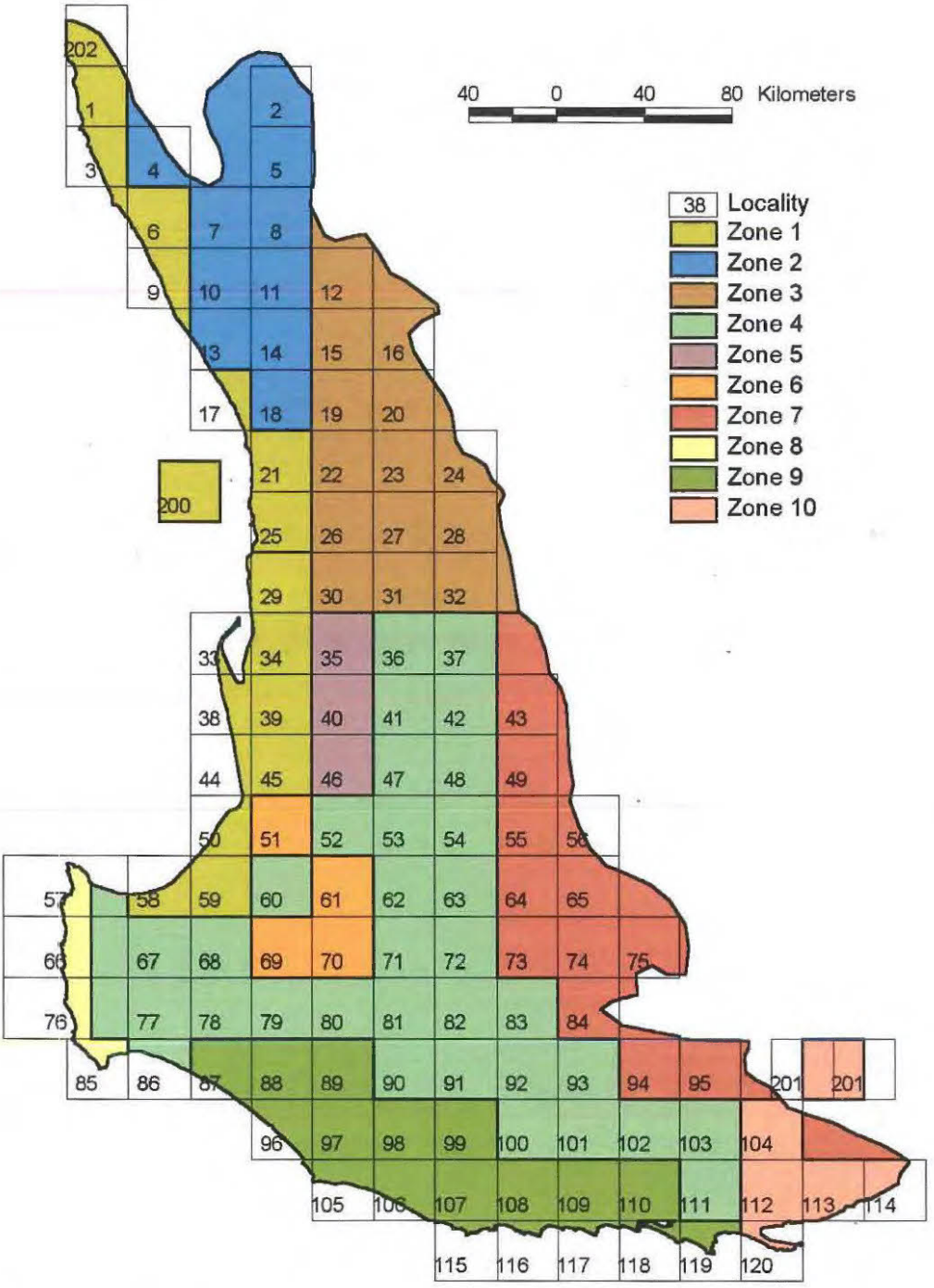
6.2.3. SUMMARY OF SOUTHERN LANDSCAPES

Southern forested landscapes (e g. Northcliffe LU 25, Deep River LU 26, Denmark LU 27) are more diverse than those in central forested landscapes. High landscape diversity was a result of the presence of all regionally distributed taxa, the wetter component of the forest taxa, and many locally distributed high rainfall taxa. Diversity was comparable to northern landscapes. However, in the south, local distributions were confined by the presence of high rainfall karri forest and its production of logs, leaf and bark litter, and not by landform. Point diversity was consistently higher at sites in southern landscapes, probably reflecting higher rainfall and less seasonal drought. There were also no sites of low point diversity within the karri forest.

The Albany (LU 28) landscape unit, which has less annual, and less reliable, rainfall, had landscape diversity comparable to that of the wetter more westerly landscape units described in the previous paragraph. Although not as high as the Perth LU (LU5), landscape diversity was due to the occurrence of regional taxa, some forest taxa and high rainfall taxa at the eastern limit of their geographical ranges. Perhaps more significant is the contribution of locally distributed taxa found only within the Albany, and sometimes the Denmark landscape unit (LU 27). These were mainly coastal taxa, all less reliant upon leaf litter. Underlying causal factors of patterns in the Albany LU are similar, to some degree, as those described for northern landscapes. Both districts are on the fringe of the high rainfall areas and have both coastal taxa, and taxa associated with geomorphological features. The landscape diversity of the Albany landscape unit is likely to be higher than shown in the last chapter because sampling has probably not yet accounted for the diversity of landforms as it has in northern landscapes.

6.3. BIOGEOGRAPHIC MODEL

Figure 6.1 shows the biogeographic model for south-western Australia. Each of the ten zones was named according to one or more representative localities and with reference to the type of landscape it contains. Detailed methods were given in Section 2.6. The data for each of the zones are presented by a table and two figures, Table 6.1, Figures 6.2 and 6.3. Table 6.1 shows a reorganisation of the data presented as biogeographical patterns, similar to that given in Table 4.3, but with additional data, namely the geographical extent of each zone, the number of unique sites, landscape diversity (number of taxa) and the number of taxa endemic to each zone. Figure 6.2 presents a series of histograms showing the number of taxa found in each zone according to the biogeographical pattern of which they were part. Figure 6.3 shows a series of bar graphs displaying the microhabitat data for all the taxa in each zone in a manner identical to that of Figures 4.21 to 4.29 presented with the biogeographical patterns in Chapter 4.



Zone 1. Perth-Bunbury Coastal Woodland	Zone 6. Bridgetown-Nannup High Forest
Zone 2. Yatheroo-Muchea Sand Plain	Zone 7. Kojonup Woodlands
Zone 3. Beraking-Wannamal Rocky Forest	Zone 8. Leeuwin-Naturaliste Ridge
Zone 4. Whicher-Wandering-Barker Forest	Zone 9. Pemberton-Denmark Karri Forest
Zone 5. Nanga Wet Forest	Zone 10. Albany Ranges

Figure 6.1. A biogeographical model for south-western Western Australia showing ten zones based upon the allocation of localities to a zone.

Table 6.1

Summary of the area, records, microhabitat utilisation, diversity and endemism of each zone of the biogeographic model shown in Figure 6.1. A key to the zone numbers was give in Figure 6.1 on the previous page.

Zone	Area (Km^2)	Unique Sites	Number of Records				Generic Microhabitat Category (%)					Taxa Summary	
			N	Pitfall traps	Without data	With data	Litter	Logs	Bark	Rocks	Other	Landscape Diversity	Endemic to zone
1	9052	115	749	336	269	144	45.8	18.1	6.9	18.8	10.4	27	2 (7.4%)
2	8983	14	53	0	7	46	52.2	23.9	0	23.9	0	13	0 (0%)
3	11964	94	593	220	47	326	37.1	45.1	8.0	8.8	0 9	30	3 (10.0%)
4	21819	34	149	0	4	145	64.1	32.4	2.8	0.2	0	19	0 (0%)
5	1942	8	60	0	2	58	79.3	12.1	6.9	1.7	0	10	2 (20.0%)
6	2583	10	67	0	3	64	65.6	28.1	1.6	1.6	3.1	12	1 (8.3%)
7	9040	9	42	0	6	36	47.2	27.8	11.1	11.1	2.8	12	1 (8.3%)
8	875	24	214	88	18	108	51.9	14.9	15.7	1.9	15.8	17	1 (5.9%)
9	8148	67	477	13	123	341	56.6	18.5	22.8	1.2	1.2	23	7 (30.4%)
10	2824	29	108	23	15	70	70.0	8.6	15.7	5.7	0	19	3 (15.7%)
Total	77230	404	2512	680	494	1338	-	-	-	-	-	60	20 (33.3%)

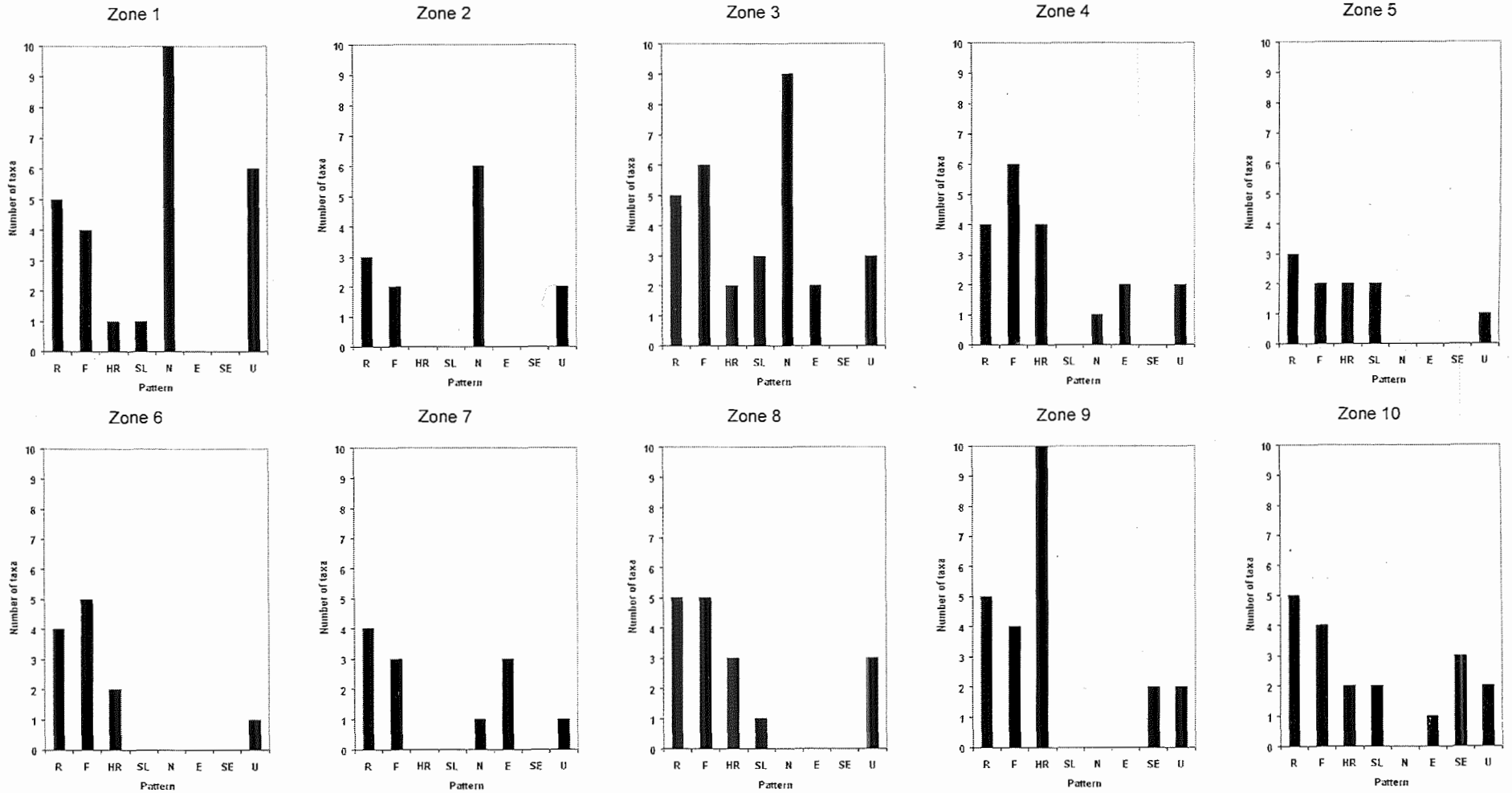


Figure 6.2. The number of taxa in each zone shown by the biogeographical pattern in which they occurred (R = Regional, F = Forest, HR = High Rainfall, SL = Single Locality, N = Northern, E = Eastern, SE = South Eastern, U = unclear. The top row shows zones 1-5 and the bottom row zones 6-10.

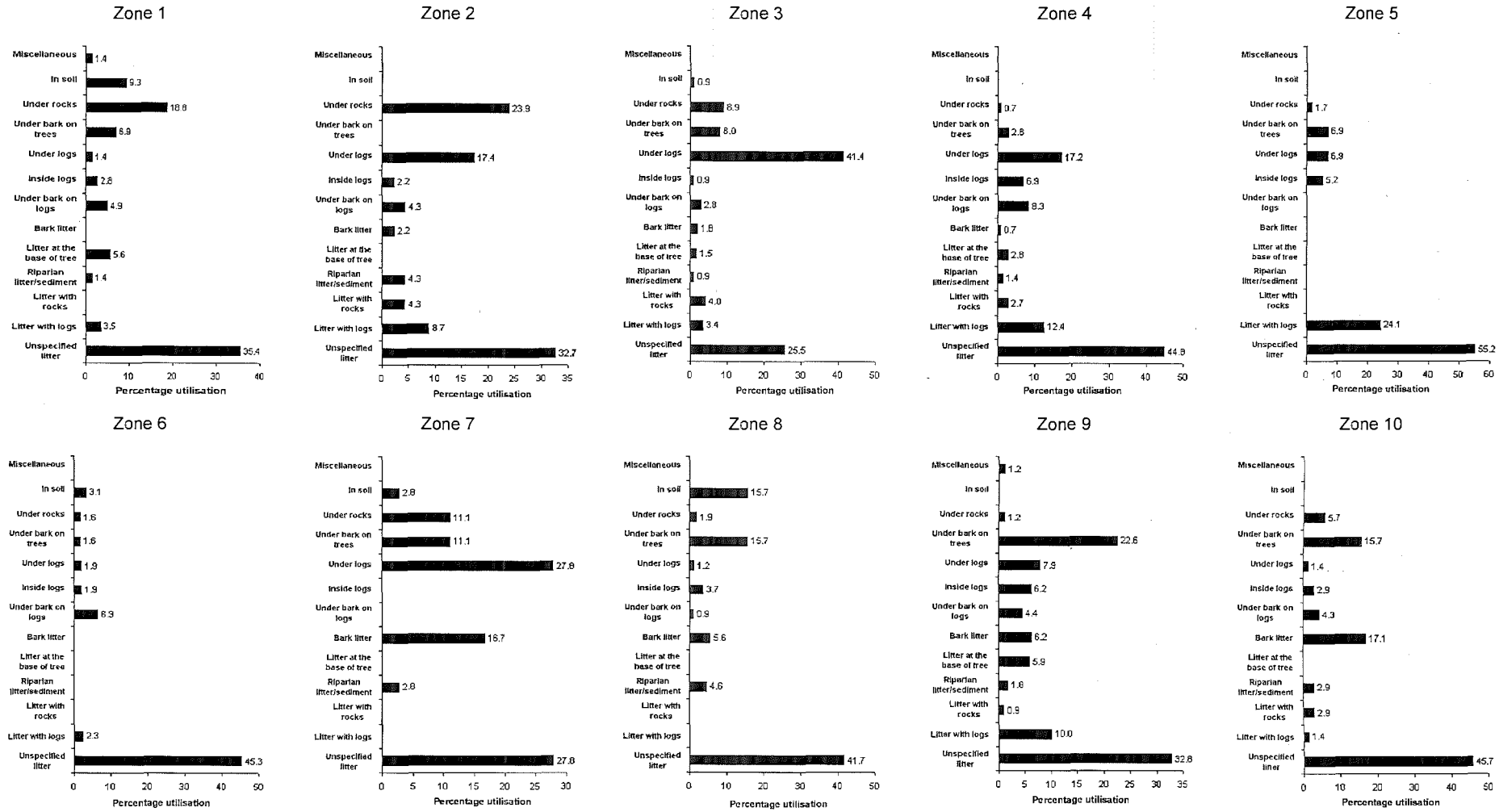


Figure 6.3. The percentage microhabitat utilisation for all taxa present in each of the zones. The classification is the same as that shown in Figures 4.1 to 4.29 in Chapter 4 and a generic summary of the same data were shown in Table 6.1. The top row shows zones 1-5 and the bottom row zones 6-10.

Each zone is now described. Descriptions include the key taxa, present or absent, contributing patterns, the richness of the zone and the degree and scale of endemism within the zone. Overall one third of the taxa were endemic to a zone.

6.3.1. DESCRIPTION OF THE BIOGEOGRAPHIC ZONES

Zone 1 (Perth-Bunbury Coastal Woodlands) had twenty taxa, the second highest landscape diversity of all zones (Table 6.1). Not surprisingly, taxa forming Northern Patterns accounted for over a third. It had all regionally distributed taxa and all the forest taxa except the largely log-dwelling Acanthodillo species 2 and 5. All but one (the forest litter-dwelling Eurygastor) of the taxa with unclear distributions, were present in this zone. Single locality and high rainfall taxa made very little contribution to this zone and only two taxa were endemic to the zone. Endemism was reduced because distributions in this part of the region were at the local scale. Therefore, many taxa found predominantly in this zone have minor representation in Zones 2 and 3. Microhabitat utilisation in this zone is varied. Generic litter habitats represent 45.8% of the records but all categories have significant representation (Table 6.1). Refuge under rocks and logs, and in soil, is particularly significant in this zone (Figure 6.3).

Zone 2 (Yatheroo-Muchea Sand Plain) had low diversity for a relatively large zone. Seven of the thirteen taxa found here were of the mainly xeric Buddelundia. There were no endemics; most of the taxa were very widely distributed taxa occurring at the north of their range. The majority of taxa were outliers from northern patterns. There were three regional taxa and outliers of two forest taxa (Figure 6.2). Rocks were more important here than in any other zone and accounted for 23.9% of records (Figure 6.3). Except for the near-coastal Buddelundia species 3 found mainly in Zone 1, all taxa found in this zone were found in the neighbouring Zone 3.

Zone 3 (Wannamal-Beraking Rocky Forest) had the highest landscape diversity of all zones (Table 6.1). All regional and forest taxa were found here and nine of the twelve northern pattern were present (Figure 6.2); only the coastal Northern Pattern taxa were absent. The zone contained northern distributions of two high rainfall taxa, Styloniscus species 6 and Buddelundia species 5. Three single locality taxa accounted for the zone's endemism, reflecting the importance of the Darling Scarp. The most notable feature of microhabitat utilisation in this region is the dependence upon logs (Table 6.1), which accounted for 45.1% of records. In this seasonally dry zone, logs not only provide moist refuge for the regionally distributed taxa but appear fundamentally important to northern taxa. However, all litter types of litter habitats were still well-utilised (Figure 6.3). Litter is important, particularly in association with local landscape characteristics.

Zone 4 (Whicher-Wandering-Barker Forest) was the largest of all the zones but had only moderate landscape diversity and no endemic taxa (Table 6.1). Diversity was derived mainly from four of the five regionally distributed taxa, all of the forest taxa and outliers of only four of the fourteen high rainfall taxa (Figure 6.2). As discussed in Forest Patterns

(Section 4.4) regionally distributed Pseudodiploexochus species show a north-south disjunct distribution. Remarkably, this zone has no records of Pseudodiploexochus species 1 and very few records of Pseudodiploexochus species 2. These are principally litter dwellers, and litter habitats accounted for 64.1% of the records for this zone (Table 6.1). Apart from the log-dwelling Styloniscus species 6, which was found at only two sites, the other high rainfall taxa (Pseudolaureola wilsmorei, Pseudolaureola new species 1 and Platyarthridae species 3) were found on the extreme edges of the zone. Consistent with a forest zone, litter (64.1%) and logs (32.4%) were the primary microhabitats. The use of logs was second only to that of Zone 2.

Zone 5 (Nanga Wet Forest) was the second smallest of all the zones. It had the lowest landscape diversity with ten taxa, but two of them were endemic (Table 6.1). Additionally, Pseudolaureola new species 1 was found marginally outside the southern boundary of this zone (see previous paragraph). The zone had three regionally distributed species, both species of Laevophiloscia and the more widespread of the Pseudodiploexochus, species 2. Surprisingly, only two of the forest taxa were found in this zone; the litter and log dwelling Styloniscus species 1 and the widespread generalist Spherillo species 5. The endemic Pseudodiploexochus species 3 and the near endemic Pseudolaureola new species 1 are both litter dwellers. The dependence upon litter in high rainfall areas of the jarrah forest is highlighted by microhabitat utilisation for this zone. Litter and litter with logs are by far the most utilised (Figure 6.3). Generic litter habitats accounted for 79.3% of records, the most for any zone (Table 6.1). As with the larger forest zone (Zone 4), logs were the only other microhabitat of note (Table 6.1, 12.1%). This zone had the lowest landscape diversity, the greatest dependence upon litter and the second highest percentage of endemic taxa. Zone 3 immediately to the north had the highest landscape diversity and the least dependence upon leaf litter. However, the inventory diversity of the wetter forest zones may be higher because the taxonomy of high rainfall litter-dwellers such as Laevophiloscia, Styloniscus and Pseudodiploexochus is the least resolved. Further taxonomic resolution will reveal multiple cryptic species.

Zone 6 (Bridgetown-Nannup High Forest) had taxa similar to those found in Zone 5. However three more forest taxa were present here, Styloniscus species 7, Acanthodillo species 6 and the xeric Buddelundia nitidissima. The zone is about 25% larger than Zone 5 (Table 6.1) and encompasses much greater landscape diversity. Taxa in this zone seem to be more widely distributed than in Zone 5. The zone was only slightly more diverse than Zone 5 but was different in that it lacked any endemic single locality taxa. The zone was different from the larger forest Zone 4 because of the presence of three taxa: the locally distributed high rainfall Pseudolaureola new species 2, which was endemic to the zone; significant northern outliers of the sub-regionally distributed Buddelundia species 6, which was found widely throughout Zone 9; and, perhaps the most interesting occurrence, the presence of the otherwise coastal Buddelundia nigripes. The microhabitat utilisation patterns of this wetter forest zone were similar to those of Zone 5. Generic litter utilisation (65.8%) was second only to Zone 5 (Table 6.1) and,

again, logs were the only other microhabitat of note. Log utilisation of 28.1% was second only to that of Zone 3 (Table 6.1).

Zone 7 (Kojonup Woodlands) had landscape diversity of twelve taxa (Table 6.1). All regional taxa, except Pseudodiploexochus species 2, were present but found only occasionally within the zone. Half of the forest taxa were present (Figure 6.2), the very widespread Spherillo species 5, the xeric Buddelundia nitidissima and the cryptic Acanthodillo species 5. There were single outliers of the northern Spherillo species 4 and the swamp-dwelling Hanoniscus tuberculatus but the zone is characterised by the presence of three taxa from eastern patterns. The locally distributed Buddelundia species 2[14], which actually occurs outside the region, was found on the fringe of the zone, and was therefore considered as part it. All microhabitats were utilised in this zone, and litter accounted for the most records (Table 6.1). Bark litter (E. wandoo) was an important component of the litter category (Figure 6.3) and, in common with the drier forest Zones 2 and 4, logs were also well utilised.

Zone 8 (Leeuwin-Naturaliste Ridge) was the smallest of all zones (Table 6.1) but had average landscape diversity (Table 6.1). It had only one endemic species, the single locality litter dwelling Styloniscus species 4. Its richness was derived from all of the regionally distributed species, all but one of the forest taxa (although the presences of the xeric B. nitidissima is marginal to the zone) and outliers of the three most widely distributed high rainfall taxa (Figure 6.3). Three unclear pattern taxa were present, all possibly coastal species. Leaf litter utilisation was lower than forest zones but higher than the coastal Zone 1. The second highest number of records for a microhabitat category was under tree bark (Figure 6.3) which is representative of the outlying distribution of karri forest in this zone. Soil utilisation was highest in this zone representing some small-scale sampling of the freshwater springs and seeps in coastal parts. These are likely to be areas of extreme importance to endemism in the zone, to which the extensive coastal cave system will also undoubtedly contribute. Samples of Pseudolaureola wilsmorei collected from swamps in the far south of the zone differ from those collected elsewhere and may represent a different species. Indeed, there were some differences in the overall size of the animal and in the length of the spines in all four of the populations of P. wilsmorei shown in Figure 4.11. The further from the centre of the Warren Bioregion distribution that a specimen was collected, the shorter the spines were. Further taxonomic work is needed in order to establish whether there are more than one species or whether this is a clinal feature. Except Pseudolaureola new species 3, which is spineless, there appears to a correlation between the annual rainfall and the length of spines.

Zone 9 (Pemberton-Denmark Karri Forest) had both high landscape diversity the highest endemism. Over thirty percent of the taxa found there were endemic to the zone. The

[14] I have since examined specimens that extend the distribution of this species eastward but not into other zones shown here.

zone had all the regional taxa, all the forest taxa, except the log-dwelling Acanthodillo associated with drier forests, and all high rainfall taxa except those endemic to Zones 5 and 6. Endemic taxa were either locally distributed or restricted. Microhabitat utilisation was most diverse in this zone with significant representation in all categories except those with soil and rocks (Figure 6.3). As has been discussed previously (Subection 4.5.1), karri trees are important throughout the Warren Bioregion, and nearly a quarter of all records come from under karri bark (Figure 6.3).

Zone 10 (Albany Ranges) had taxa from all patterns except Northern (Figure 6.2). As discussed in the previous patterns of diversity, the presence of the Porongurup (Locality 104) and Stirling Ranges (Supplementary Locality 201) influenced dramatically the diversity of this zone. Three endemic taxa were found here, the coastally restricted Cubaris species 4, the single locality Australoniscus springetti found at the Porongurup Range, and Pseudolaureola new species 4 found in the far east of the zone. Endemism for the zone was 15.7%, third highest after the wet forest zones, Zone 9 and Zone 5. Like Zone 5, this higher endemism was accompanied by high dependence (70%) on leaf litter (Table 6.1). However, this is largely the influence of the Porongurup Range. South-eastern Patterns (Section 4.9) showed that rocks and logs were important in coastal areas. There is a similarity between the microhabitat utilisation in Zone 10 and the coastal Zone 1. In a sense, Zone 10 has the combined properties of Zones 1 and 3 but on a smaller scale.

6.4. REGIONAL FACTORS INFLUENCING PATTERNS

It has been argued that the number of species an area contains will increases proportionately with size (Lomolino, 2001). Alternatively, a "habitat diversity" hypothesis proposes that a larger area will contain more species because, when larger areas are sampled, new species will be included as more habitat types are sampled (Whittaker, 1998). The effects of increasing area and habitat heterogeneity can be difficult to separate (Johnson et al., 2003), and the the question of which is more important has been the subject of continuous debate. However, it is not practical or necessary to repeat it here. Some authors (e.g. Triantis, 2003) suggest that the species richness does not depend solely upon area or upon habitats, but on both of them. In the case of terrestrial isopods, Sfenthourakis (1996b) concluded that habitat diversity seemed to be the greater determinant of species richness, although the species-area relationship was still important. In the light of these observations, this section aims to identify some of the important factors determining the number and types of species found within the zones.

Across all zones, terrestrial isopod communities changed over relatively short distances. Site factors were extremely important in determining species composition at any given point in the landscape. The degree to which microhabitats were present, and probably, their properties, influenced the number and type of taxa present. This suggests a large degree of microhabitat heterogeneity. Habitat heterogeneity refers to the relative amount

of variation in pre-existing characteristics within a given area (Hart & Horwitz, 1991). The diversity of microhabitat types within a defined area will contribute to terrestrial isopod species diversity of the area (Sfenthourakis, 1996b). It is not the purpose of this section to assesses the applicability of these models to the terrestrial isopod fauna of south western Australia, but, since natural areas of varying sizes with different landscape diversities have been defined in this chapter, some insight of the underlying causes of regional diversity may be gained by examining the species-area relationship for the ten zones. A species area relationship among zones of differing size and diversity may be representative of similar underlying causal factors.

Figure 6.4 shows the relationship between landscape diversity (species richness) and area for the ten zones. The data were given in Table 6.1. The most obvious feature is that there is no statistical relationship between the size of the landscape zones and their diversity ($r = 0.416$, $df = 8$, $p > 0.05$). The largest zone (Zone 4) was not the richest, nor was the smallest (Zone 8) the least rich. There were however some interesting relationships among the zones.

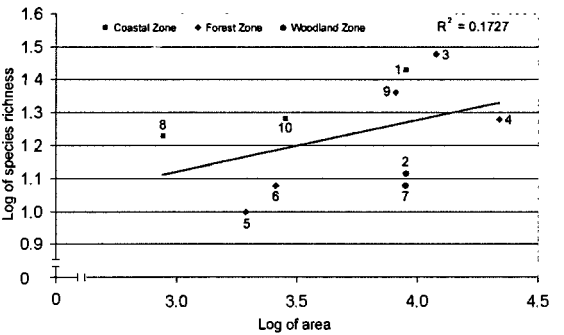


Figure 6.4. Species area relationships for the different zones shown in Figure 6.1. The zones (zone numbers are shown on the graph) are classified as to whether they are principally forest, coastal or woodland zones.

Figure 6.4 shows the zones coded as to the type of landscape the zone contained. The woodland zones occupying the lower rainfall areas in the north east (Zone 2) and east (Zone 7) had virtually identical areas and species richness. Diversity was less than the larger forest zones, perhaps because of drier and a more open vegetation structure. Among the forest zones themselves, there were some interesting relationships. The relatively smaller wetter forest zones (Zones 5 & 6) were much less rich than the larger forest zones (Zones 3, 4, & 9). Among the three wetter forest zones (Zones 5, 6 & 9)

there was a strong positive relationship between area and species richness. It seems that where species are relying upon surface organic matter for microhabitat, the species-area relationship is important. This suggests that if the wet forest zones were to contract, as a result of a drying climate, local extinctions would occur. The effect of high rainfall is shown by the richness of Zone 9, incorporating the main distribution of karri forest. It is comparable in area to the woodland Zones 2 and 7 but has nearly twice as many taxa. Point diversity also was greater in the wet southern forests. This is probably due not only to higher rainfall, but also to its greater reliability, reduced seasonality and more productive forests. The fact that high rainfall patterns contained the most taxa also suggests that rainfall clearly is an important factor in determining terrestrial isopod distribution and diversity

The influence of the coast and coastal landscape was shown by the relatively high richness of Zone 10 (Albany Ranges) and particularly the smallest zone (Zone 8, Leeuwin-Naturaliste Ridge). Both these zones were richer than similar sized wet forest zones, although both, and Zone 8 in particular, contain outlying pockets of wet forest. The two zones in the north of the region were both large and species rich. The influence of the coast is perhaps less important here in that the coastal Zone 1 was less rich than the forest Zone 3.

The low diversity and small area of Zones 5 and 6 hides the fact that they are important centres of endemism. At some sites in Zone 6, point diversity contributed much more to the overall of the landscapes diversity than it did in other zones. This was particularly evident in Bridgetown (Locality 70) locality, where a single site contributed the entire richness for both the locality and the landscape unit (LU 17). Much of this zone, which is the topographically highest part of the region, contains a forest landscape that is heavily fragmented by cleared farmland and pine plantations. Therefore, much of the diversity in this zone is contained in forest fragments. It is evident that much of the high rainfall jarrah and karri forest needs more intensive small–scale sampling. The number of sites here may not be adequate to represent fully the small scale of endemism. Since there are likely to be positive relationships between the richness of terrestrial invertebrates and productivity (Waide et al., 1999), and moisture and productivity of plant communities (Suding & Goldberg, 1999), the diversity of terrestrial isopods in wet forest zones will be influenced by both moisture and productivity and the relationship between them.

While Zones 1 and 3 are undoubtedly species rich, and contain a large degree of habitat heterogeneity, richness may be due in part to greater taxonomic clarity in the Armadillidae. The Buddelundia in particular occur in drier parts of the region, and the better taxonomic resolution for this genus adds to the clarity of the patterns within the north of the region. In contrast, the regionally distributed litter dwelling forest taxa such Laevophiloscia and Styloniscus have poorer taxonomic resolution. Greater resolution of these taxa would certainly add to inventory diversity in all landscapes but particularly in wetter forests Zones 5, 6 and 9 where they are more common. Greater taxonomic

resolution would also allow for much greater clarity of fine scale biogeographical boundaries.

This and the preceding two chapters have identified some principal factors likely to underly the regional diversity of terrestrial isopod in south-western Australia. These are:

(1) High rainfall;

(2) superficial geology;

(3) latitude and longitude;

(4) site productivity;

(5) nature of surface organic matter;

(6) speciation patterns; and,

(7) exogenous disturbance.

The influence of the first three factors is relatively straightforward and has been discussed in relation to the individual patterns. The others require further consideration. The role of organic matter appears critical and differs in areas of high and low rainfall. It is in areas of higher rainfall where it is most important to the regional diversity of terrestrial isopods because it provides microhabitat for restricted endemics. The region's forests contain many widely distributed taxa all utilising organic matter. However, endemism is derived from single locality, restricted and some local scale taxa dependent upon it. Lower rainfall areas are usually composed of many co-occurring local patterns in which organic matter is utilised less. The scale of patterns in the driest eastern parts of the region is difficult to interpret due to the increasing area of cleared land and consequential lack of distributional data. However, there seemed to be increasing use of more cryptic microhabitats in these areas and a reduced dependence upon leaf litter. The role of surface organic matter appears to be of fundamental importance to the present day distributions of terrestrial isopods and therefore is likely to have influenced, and continue to influence along with changes in rainfall, the patterns of speciation of the group within south-western Australia.

Different types of organic matter contribute to the regional diversity of terrestrial isopods in different parts of the region. The key to understanding the role of organic matter is to understand which of its properties are important to the provision of microhabitat. The properties of organic matter are related to a number of the other factors, namely rainfall, landform, productivity and exogenous disturbance. The way that organic matter responds both spatially and temporally to these factors will determine the distribution of terrestrial isopods at all scales. The key questions thus become: 1) which properties best describe the distribution of terrestrial isopods at the small scale and how can these be extrapolated to larger scales to explain the regional diversity of terrestrial isopods both now and in the past; 2) are there consistencies in the relationships between organic

matter and moisture between zones or is this relationship zone specific; and 3) are the distribution of organic matter and its properties good surrogates for the other variables?

The following chapter explores in detail, the influence of epigean organic matter properties upon the patterns described in Chapter 4 and Chapter 5, and assesses their role in producing and maintaining the distributional patterns of the region's terrestrial isopods. A final chapter will draw some conclusions as to the validity of the model, re-examine the concepts of landscape and regional differentiation in light of the more meaningful landscape units defined in this chapter, and hypothesise as to the historical reasons for the patterns we see today. Finally, in order to determine potentially threatening processes to the conservation of such extraordinary endemism and diversity, the thesis concludes by evaluating the extent to which exogenous disturbance might have influenced the patterns evident today.

CHAPTER 7

SURFACE ORGANIC MATTER

7.1. INTRODUCTION

The previous chapter depicted a moisture-dependent group of animals, in a seasonally dry landscape, showing different degrees of dependence upon surface organic matter for the provision of microhabitat. Surface organic matter appears to be fundamentally important in high rainfall areas and accounted for the distribution of many short-range endemics. It follows then that changes in the production, decomposition and temporal distribution of surface organic matter will affect the spatial distribution of terrestrial isopods. Furthermore, surface organic matter may be important characteristics of the zones shown in the last chapter. This chapter pursues these hypotheses by investigating the relationship between properties of surface organic matter and the distribution of the taxa discussed previously.

Terrestrial isopods consume dead organic matter (Hassall, Turner, & Rands 1987; Zimmer, 2003) and are therefore intractably linked to the decomposition cycle. Most species are primarily saprophagous, reliant upon litter and other organic inputs in the habitat in which they live. The micro-scale spatial distribution of terrestrial isopods is patchy and is governed by differences in available food quality (Rushton & Hassall, 1983; Zimmer & Topp, 1997; 2000; Kautz, Zimmer & Topp, 2000) and microhabitat (Heinzelmann et al., 1995). Isopods, as a conspicuous part of the soil and litter macrofauna, have body sizes large enough to disrupt the physical structure of the soil during foraging and feeding activities, and are considered generally to increase decomposition by exposing a greater surface area of the resource to microbial attack (Anderson, 1988).

The provision of both food and microhabitat in Western Australian landscapes will be the result of differences in the production of litter (litterfall) and the rates at which it breaks down. Litterfall causes the accumulation of a litter layer, usually directly on the soil surface. The breakdown of this material and its integration with the soil results in soil stored organic carbon. Dead branches and trees, often termed fallen wood, or coarse woody debris (CWD) (e.g. MacNally et al., 2001), also contribute to the carbon store and are an important structural and functional component of temperate forest ecosystems (Harmon et al., 1986). CWD often accounts for 17-64% of organic matter within forest ecosystems (Harmon, Cromak Jr. & Smith, 1987). The size of CWD relative to that of leaf litter means that a much longer period of time is needed before it decays to finer fractions and eventually becomes integrated into the soil. CWD in its own right is considered of vital importance to the forest biodiversity (see references in Marra & Edmonds, 1998; Harmon et al., 1986).

The breakdown of organic matter is mediated by the synergistic activities of the litter and soil flora and fauna, and leaching by rainfall. In Western Australian forests, rainfall removes a great deal of the nutrients from eucalypt litter relatively quickly while microbial digestion of cellulose takes a good deal longer (O'Connell & Menagé, 1983). Litter is a

source of energy for the decomposer community but the rates of activity of soil and litter saprovores are often controlled by external variables (Spain, 1984). Central to the relationship between litter and decomposer activity is moisture. Whilst litter decomposition is affected directly by environmental factors such as temperature and rainfall, micro-scale conditions can be mediated by moisture stored in the organic matter and the soil (Howard & Howard, 1980). Moisture is an important factor in the decomposition process (Woods & Raison, 1983) although the actual processes by which seasonal drying in Australian forests slows the decomposition process have not been investigated.

The relationship between organic matter and moisture is a reciprocal one. The breakdown of organic matter depends on moisture whilst litter cover can influence profoundly patterns of moisture retention with the landscape. Litter modifies soil temperature by intercepting solar radiation and by insulating the soil from ambient air temperatures (Facelli & Pickett, 1991). In seasonally dry landscapes, litter cover will buffer the soil surface and lower litter strata from both seasonal and diurnal extremes of temperature. Woods and Raison (1983) showed a distinct pattern in litter decay for Australian eucalypt forests. A rapid period of leaf decay following litterfall, due to leaching and respiration of water-soluble organic carbon by micro-organisms, was followed by a slower period of decay dependent upon litter moisture and temperature.

The presence of litter has profound effects upon the exchange of water between the soil and the atmosphere (Facelli & Pickett, 1991). This varies considerably with the type of vegetation studied but, in general terms, litter cover will produce patchiness in soil moisture. Litter on the soil surface can increase soil moisture, relative to areas where litter is absent, by reducing evaporation (Holland & Coleman, 1987). Litter affects evaporation directly by increasing the resistance to water vapour diffusion from the soil surface and indirectly by reducing the temperature at the soil surface. In some circumstances, litter cover may reduce soil moisture by intercepting and absorbing rainfall that would otherwise reach the soil surface (Facelli & Pickett, 1991). Clearly, there are a number of factors involved here. The condition of the litter prior to a rainfall event will affect its hydrological properties. Hydrophobic litter, which has been subjected to prolonged drying, may not retain much water and result in surface flow rather than in situ infiltration. Hydrophobic organic compounds derived from decomposing litter, fungal hyphae and micro-organisms have been documented from Australian soils (Ma'shum, Tate, Jones, & Oades, 1985) and can give rise to uneven spatial patterns of water infiltration following wetting (Garkaklis, Bradley & Wooler, 1998). This may result in the greater wetting of soil not covered by hydrophobic litter or water flow underneath the litter. The duration and periodicity of rainfall events also determine the role of litter in moisture retention. Litter in general can absorb a higher proportion of water from fewer or smaller rainfall events than from larger or longer ones (Facelli & Pickett, 1991). In addition, Voigt (1960) showed that rainfall is irregularly distributed under a forest canopy due to the presence of soil moisture resistant units.

Literature dealing with the temporal and spatial distribution of organic matter on the floor of Australian forests has usually focused upon one of two issues. The accumulation of organic matter in relation to fire behaviour and ecology (e.g. Birk & Bridges, 1989; McCaw, Neal & Smith, 2002) or nutrient supply and recycling, with forest floors performing the role as a nutrient sink for plant growth (e.g. Turner & Lambert, 2002, O'Connell, Grove & Dimmock, 1978; O'Connell 1987; Hutson & Veitch, 1985, O'Connell 1986). Very few studies have included the decomposer community as a variable in these processes and, with only a few exceptions (e.g. Ashton, 1975), are they ever documented. Litterfall is often used as a surrogate for productivity (e.g. O'Connell, 1988) and litter nutrient recycling rates as a surrogate for ecosystem functioning (e.g. Turner & Lambert, 2002). There is a general consensus that annual litterfall declines with decreasing rainfall (Grigg & Mulligan, 1999) and is strongly seasonal, with maximum litterfall occurring usually in late summer and autumn (e.g. Ashton, 1975, Lee & Correll, 1978; McIvor, 2001). The ratio of the annual input of dead organic matter (litterfall and production of CWD) and the standing crop of litter and logs on the forest floor is often used to calculate a rate of decomposition (Turner & Lambert, 2002). This assumes a steady state and that equilibrium in the two processes has been reached. Questions of equilibrium and the time scale appropriate to their definition were discussed by Turner and Lambert (2002) who concluded that equilibrium is rarely achieved.

Terrestrial isopods are not only dependent upon litter properties as a food source but also for moisture, perhaps the single most important microhabitat characteristic in seasonally dry landscapes. Where terrestrial isopods have been included as a component of studies of litter and soil in Australian forests, they usually show differing abundances among variables measured (Ashton, 1975; Neumann, 1991), and are, in studies comparing burnt and unburnt forest sites, routinely much less abundant following fire (Springett, 1976, 1979; Neumann & Tolhurst, 1991; Collet, Neumann and Tolhurst, 1993; Collet, 1999). Most studies (except Springett, 1976 see Subsection 3.2.3) are analysed at the ordinal level and so lack a detailed insight in the nature of terrestrial isopod responses in such studies. Furthermore, all of these studies, but again with the notable exception of Springett (1976), relied mainly or entirely upon pitfall traps. These are not entirely effective for sampling terrestrial isopods as was show in Chapter 5.

An insight into the influence of microhabitat properties upon the terrestrial isopods of the region comes from the analysis 477 samples of soil, litter and logs. Collection details were given in Subsection 2.4.4 and details of their analysis in Section 2.7. These cover the entire region and consist of standardised samples of either litter, litter and soil, pieces of logs or tree bark, or soil samples by themselves. Samples were analysed to determine relationships among microhabitat properties and the isopods that were found in them. The principle limitation of this analysis is that the dataset does not include samples from microhabitats where isopods were not found. This however does not preclude an investigation of the differences in properties among the taxa.

Since a regional examination of the microhabitat properties of terrestrial isopods is being undertaken, the logical place to start would be to see whether microhabitat properties can classified in the same way as the taxa. The last chapter identified zones with, to some degree, different taxa occupying different microhabitats. Zonal differences in microhabitat properties would explain the distribution of the taxa, account for the model and would be singularly more important than the distributional influences outlined in previous chapters. If this were the case, a regional comparison would not be appropriate and comparisons between taxa should be undertaken at Zone level. However, if microhabitat properties were similar throughout the region, then regional comparisons between taxa would be appropriate. The aims of this chapter are to:

- determine whether microhabitat properties differ between zones;
- determine whether the presence of certain taxa is related to specific microhabitat characteristics;
- determine the relationships among microhabitat properties themselves; and,
- discuss the importance of surface organic matter to region's terrestrial isopod fauna.

7.2. MICROHABITAT PROPERTIES AND BIOGEOGRAPHIC ZONES

Microhabitat data consisted of eight main microhabitat types, but the data available for each type were slightly different. The different types of samples collected were listed in subsection 2.4.4 and a classification summary was given in Table 4.2. The results of four of these types of samples are included in this chapter, namely; (1) litter on soil, (2) under log bark, (3) inside logs; and, (4) under logs.

Since terrestrial isopods are inherently wedded to moisture, it is unlikely that there are any great differences in the moisture content of microhabitat samples between zones. Mean litter moisture content for each of the zones is shown in Figure 7.1 (bottom) and ranged from about 18% in the northern and drier Zone 1, to nearly 27% in the wet forest Zones 5 and 9. While it could be expected that the northern zone might have drier litter than the most southern zones, there was remarkably little variation among the zones considering that they represent marked latitudinal and rainfall gradients. The forest Zones 3, 5, 6 and 9 were all very similar but the largest forest zone, Zone 4, had the least moist litter and the least variation. The woodland Zone 2 was most similar to the forest zones while the moisture content of litter in coastal zones 1, 8 and 10 was similar to, but slightly less than, the forest zones. This could be due to differences in vegetation contributing to the litter or to the influence of coastal sandy soils. Overall a one-way analysis of variance of the data presented in Figure 7.1 showed no statististically significant difference in the mean litter moisture content among the zones ($F = 1.1719$, df. = 8 & 169, $P = 0.097$).

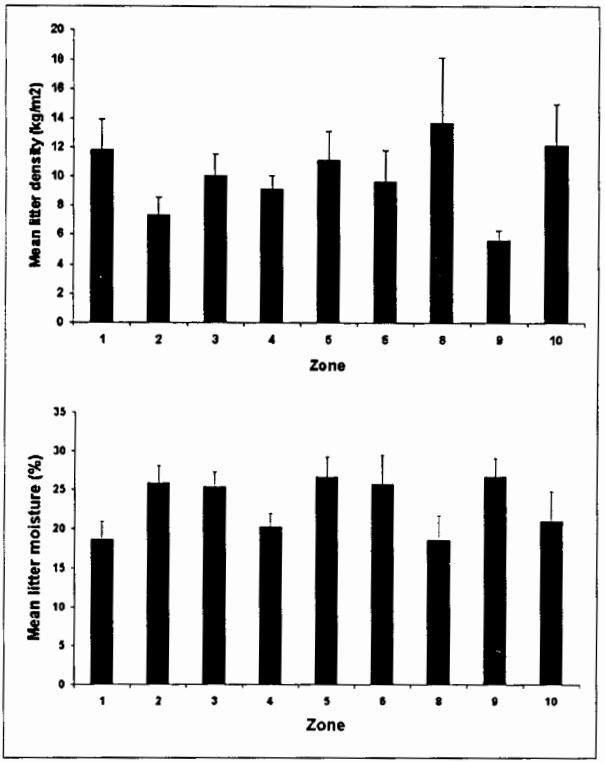


Figure 7.1. The mean litter moisture content (bottom) and mean litter density (top) with standard error bars for each zone. There were no data for Zone 7.

The pattern of variation in litter density among the zones (Figure 7.1, top) was remarkably different to that of litter moisture. It was generally much more variable and ranged from 5.6 kg/m^2 in Zone 9 to 13.7 kg/m^2 in Zone 8. Zone 9, the wettest and the most productive zone, had the lowest mean litter density. This is probably due to greater levels of decomposition aided by greater and more consistent supplies of moisture. A one-way analysis of variance showed a statistically significant difference in the mean litter density among the zones ($F = 2.171$ df. = 8 & 186, $P = 0.032$).

While some taxa might favour moister microhabitats than others, generally speaking, moisture conditions do not vary at the regional scale. However, moisture conditions may be provided for by differing microhabitat characteristics in each of the zones. Therefore, some questions are of fundamental importance here: Are some properties of, for example leaf litter, more important to the retention of moisture in some parts of the region than in others? Is litter in wet forests simply wetter than in dry forest? And, do moisture conditions vary more on a point scale than a regional one?

Figure 7.2 shows a MDS ordination of all 169 litter samples collected from a soil substrate. Each of the litter samples is represented by the zone (Figure 6.1) from which it was collected. The analysis included the properties of litter moisture content, density and the weights of the fine (<5 mm), medium (<13 mm) and the coarse (>13 mm) fraction. There appears to be no distinct grouping of samples according to zone. There are some outliers but not consistently from any zone. Most of the records form a tight group and are therefore similar in the properties measured. Zone 9, (Pemberton-Denmark karri forest) the wettest zone, is perhaps notable in that samples from this zone are the most tightly grouped. Other than Zone 9, which had remarkably low mean litter density, there is no real differentiation of zones based on the properties of leaf litter. The results were very similar for soil properties under logs so it was not considered necessary to illustrate them. Therefore, since microhabitat properties are not different in each of the zones, a regional analysis of terrestrial isopods is appropriate. However, differences in Zone 9 are obviously important and will be considered during the following analyses.

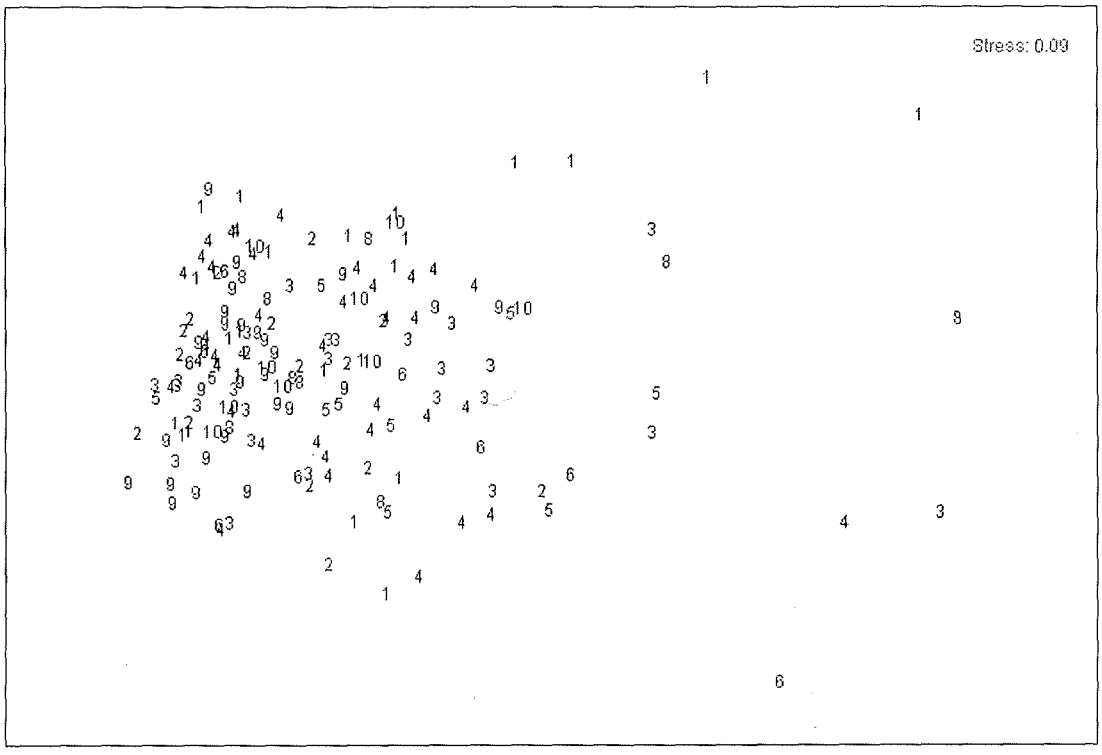


Figure 7.2. An MDS plot of all litter samples using moisture, density and fraction weight data. Each sample is indicated by the number of the zone from which it was collected.

7.3. MICROHABITAT PROPERTIES AND TAXA

Other than small variations in litter moisture between forest and coastal areas, there are no perceivable differences in the properties of litter or other microhabitats among the zones. Litter properties vary as much within a zone as they do among them. Variability within each of the zones is probably more important. The key question now becomes whether the taxa respond differently to microhabitat properties. Multivariate analyses, mainly MDS ordinations, were performed to investigate relationships between the taxa and the microhabitat properties. Such analyses showed no clear groupings of taxa based on the entire data set and were hard to interpret, because more than one taxon was often found in the same microhabitat and consequently had the same microhabitat data. This made MDS plots unhelpful because different taxa were plotted with the same coordinates. Therefore, potential relationships between individual taxa and microhabitat properties were investigated using univariate techniques. To overcome some of the taxonomic difficulties outlined previously, analyses were undertaken mainly at the generic level. This is appropriate at the regional scale and allows for a better statistical comparison because of greatly increased sample size. Generic associations are taxonomically well established and this approach overcomes the complex nature of both Laevophiloscia and Styloniscus.

7.3.1. LITTER DWELLING TAXA

Litter dwelling taxa were investigated first because they constituted by far the greatest part of the dataset. Litter samples also included more variables than other microhabitats because both litter properties and soil properties were measured. Of all the variables examined, the occurrence of taxa was influenced most by litter moisture. Figure 7.3 shows the litter moisture by percentage of dry weight for the microhabitat samples of five genera. It shows both a boxplot with medians, quartiles and the number of samples, and a bar graph with the mean moisture percentage and coefficients of variation. Taxa frequently occurred together so a single sample may represent more than one genus.

The association between the occurrence of taxa and litter moisture levels concords extremely well with the scale of distributional patterns illustrated in the Chapter 4. The regionally distributed and mobile Laevophiloscia occurs in the broadest range of litter moisture. Its median value was much less than the less widespread Styloniscus. Furthermore, at the species level, two species with similar microhabitat utilisation patterns, the predominantly forest litter-dwelling Styloniscus species 1, occurs in leaf litter statistically more moist than the regionally distributed Laevophiloscia species 2. ($t = -3.628$, $df = 135$, p (one tail) $= 0.0002$). Therefore, a need for moister litter explains very well the distributional differences in the Laevophiloscia species 2 and Styloniscus species 1. The distribution of the genus Pseudolaureola, which consists of forest endemics at the local and restricted scale, fell entirely within high rainfall patterns. Furthermore, its mean litter moisture is the highest and the least variable. Its median is little different to the

forest dwelling Styloniscus and it showed a much narrower range of occurrence in drier litter. This is quite remarkable considering that Pseudolaureola belongs to the more advanced Armadillidae equipped with pleopodal lungs, whereas Styloniscus is considered more a much more primitive form.

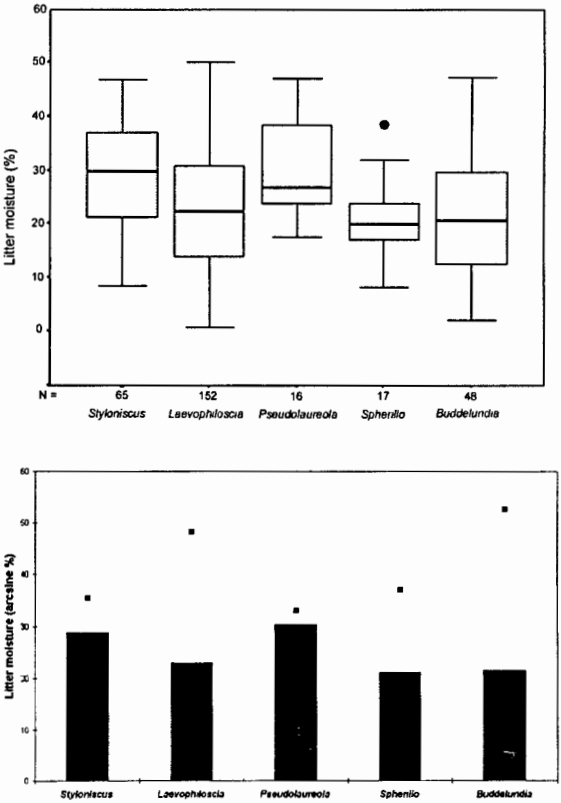


Figure 7.3. A boxplot (upper) showing the moisture content (%) (outlier indicated by circle) and a bar graph (lower) showing mean litter moisture (arcsine %) with coefficient of variation (squares) for the five most common litter dwelling genera.

The litter moisture of the restricted and litter-dwelling Pseudolaureola, contrasted strongly with the widespread Spherillo. The mean moisture content of litter for Pseudolaureola is statistically greater than Spherillo ($t = 2.939$, $df = 31$, p (one tail) = 0.003). Therefore, the restriction of the genus Pseudolaureola to the wetter forest can be explained by a dependence on moist litter.

A one-way analysis of variance (Table 7.1) showed statistically significant difference in mean litter moisture among the groups. However, it should be noted that the difference in variances between the least variable genus (Spherillo) and the most variable genus (Buddelundia) was high, although not statistically significant. Litter moisture appears to be a fundamentally important factor in the smaller scale distribution of the region's terrestrial isopods. Small-scale differences in moisture contribute to the high microhabitat differentiation evident in Chapter 5, and the seasonal availability of litter moisture is likely to be critical to the persistence of taxa at all scales.

Table 7.1

One-way analysis of variance for litter-dwelling genera data shown in Figure 7.3.

Source of Variation	SS	df	MS	F	P-value
Between Groups	980 28	4	245.07	7 00	0.000119
Within Groups	11973.33	293	40.86		
Total	12953.61	297			

All data were arcsine transformed and checked for homogeneity of variance ($F = 0.479$, $df = 16$ & 47, $p = 0.055$)

The mean moisture content of the litter samples representing Buddelundia and Spherillo were similar, although the data for Buddelundia were much more variable. This is because Buddelundia is comprised of coastal species, xeric species and two species endemic to the wet forests. When examined at the species level, the data for Buddelundia were scant. However, an interesting pattern is produced by the species that contributed to the longitudinal zonation in northern patterns illustrated in Figure 4.22 in Section 4.7. Figure 7.4 shows the mean litter moisture content and coefficients of variation of four species of Buddelundia.

The immediately coastal B. inaequalis occurred in litter with a similar mean moisture content to B. opaca and both species were from rocky zones. B. cinerascens and B. nitidissima occurred in litter of much lower mean moisture content and both are found in sandy soils where logs are an important microhabitat component. While samples are small and variable, it is possible that these species have different moisture tolerances. B. nitidissima, which is found throughout the jarrah forest and was considered a xeric species, occurs in litter that is much drier than other forest taxa. While there is no statistical difference in the mean litter moisture between Buddelundia and Spherillo, the

mean litter moisture content for the regionally distributed B. nitidissima is statistically less moist than Spherillo (t = 1.951, df = 27, p (one tail) = 0.0307).

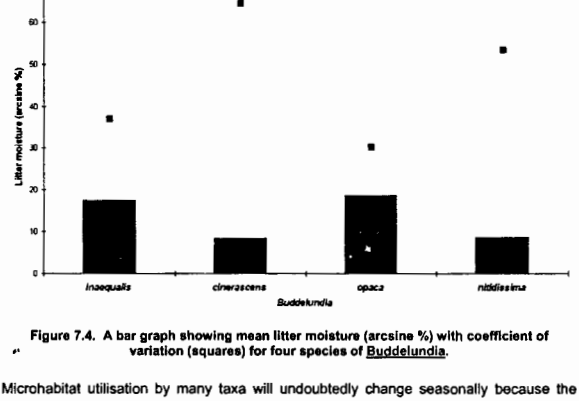


Figure 7.4. A bar graph showing mean litter moisture (arcsine %) with coefficient of variation (squares) for four species of Buddelundia.

Microhabitat utilisation by many taxa will undoubtedly change seasonally because the degree to which moisture is available in a given microhabitat will diminish as the landscape dries. Litter that was too wet previously, will become inhabitable whilst other litter will become too dry. Temporal variation in microhabitat occupation was not measured in this study. Therefore, seasonal changes in microhabitat utilisation cannot be determined. The persistence of taxa in some parts of the region will ultimately depend upon the availability of moisture at the driest times of year. Litter-dwellers may utilise other moist niches such as logs or soil during drier times, but then the key factor will be the availability of moisture. If this were true, moisture will also be the most important property of the other microhabitats recorded in this study.

7.3.2. LOG DWELLING TAXA

Microhabitat data accompanying taxa collected from logs came from one of three sources: (1) under the log; (2) under the bark on the log; and, (3) inside the log. This subsection deals with taxa collected from the latter two categories.

7.3.2.1. Under log bark

Observation of scores of logs throughout the Region revealed that log bark decays and is lost by logs in the early stages of decay, a common feature of log decomposition also noted by Pyle and Brown (1999). Therefore, the data dealing with taxa found under the bark of logs are dealing with much less-decayed logs than the data for taxa found inside

logs. The area under the bark of the log can be quite wet whereas the log itself can be quite hard and dry. Given the nature of this microhabitat, it is probable that taxa found here are quite mobile enough to occupy other microhabitats.

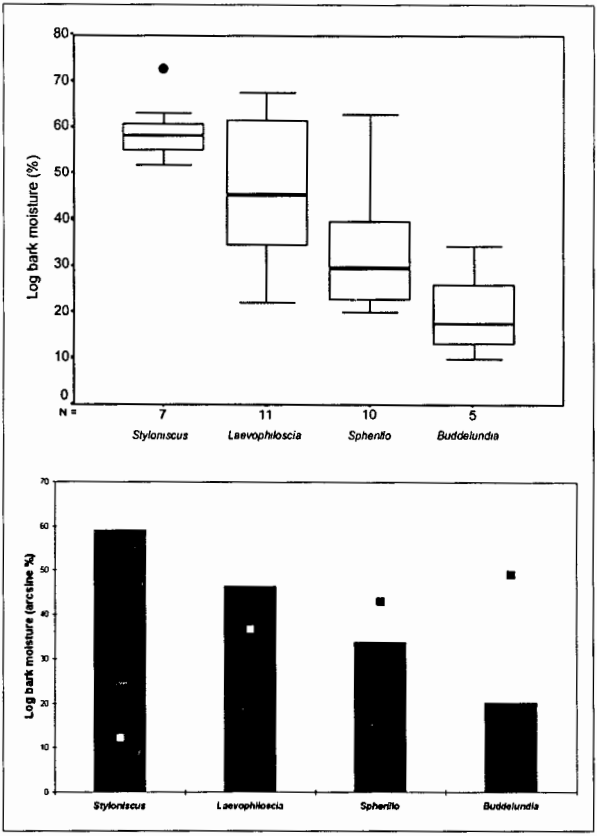


Figure 7.5. A boxplot showing the moisture content of log bark (%) and a bar graph showing mean moisture content of log bark (arcsine %) with coefficient of variation (squares) for the four most common genera occurring found under log bark. Dark circle shows outlying value of 72.8%.

Figure 7.5, in a similar manner to Figure 7.3, shows the moisture properties of log bark in relation to the four most common genera found there. With the exception of Pseudolaureola, which only occurred once in this microhabitat, the genera are the same as Figure 7.3. Log bark moisture was the only parameter recorded for this microhabitat. One of the most striking features of Figure 7.5 is the very narrow moisture range of the primitive Styloniscus. The maximum and minimum moisture values shown for this genus were 51.9% and 63.2% respectively and consequently it had the lowest coefficient of determination. The moisture range for Styloniscus is also higher and narrower than it it was in litter. Both Styloniscus species 1 and 7 were found at the lowest moisture (where they co-occurred) while the two highest values 63.2% and the outlier shown at 72.8% were only recorded for the more restricted species 7. The log with 72.8% moisture also hosted a specimen Pseudolaureola wilsmorei, the only record for this moist litter-dependent genus. The small variance of the data for Styloniscus were statistically significantly different from that of Laevophiloscia when performed on arcsine-transformed data ($F = 0.232$, $df = 6$ & 10, $p = 0.044$). This meant that an analysis by one-way ANOVA was not possible, so potentially statistically significant differences between other genera were investigated individually by means of t-tests.

There was no overlap at all in the moisture regimes of Styloniscus and Buddelundia. They occupied either ends of the moisture spectrum in this microhabitat and had the smallest ranges of data. There were however, only a few records for Buddelundia; two were for the coastal B. cinerascens, and one each for the coastal B. nigripes, the rocky forest dwelling B. opaca and the xeric B. nitidissima. Buddelundia were not found under log bark in the wetter forests. Spherillo was common under log bark throughout the wetter forests and utilised statistically significantly moister log bark than Buddelundia ($t = -1.828$, $df = 13$, p (one-tailed) $= 0.0453$). Eight of the records for Spherillo were from the regionally distributed forest-dweller Spherillo species 5 (mean moisture = 35.2%). The other two came from the sub-regional northern Spherillo species 2 (mean moisture = 4.8%) and the high rainfall Spherillo species 3 (mean moisture = 21.13%). While the distributions of the two genera overlap considerably, Spherillo and Buddelundia did not occur together.

Laevophiloscia showed the greatest range of mean log bark moisture (22.2% - 67.72%). This is understandable since both Laevophiloscia species 1 and 2 are both regionally distributed. Seven of the eleven records were for the more widespread species 1 and four were for species 2. Species 1, which was more common in association with logs, had a mean moisture content of 43.9%, while species 2, which was more common in litter, was found under log bark with a mean moisture content of 50.9%. The species co-occurred only once at a moisture content of 63.6%. The moisture content of bark for Laevophiloscia was statistically significantly greater than both Spherillo ($t = -1.820$, $df = 19$, $p = 0.0423$) and Buddelundia ($t = -3.1067$, $df = 14$, $p = 0.0039$).

7.3.2.2. Inside logs

Styloniscus and Laevophiloscia were by far the most common taxa inside logs and Figure 7.6 shows the moisture content of the logs in which occurred. There were twenty-four records for Styloniscus, twenty for Laevophiloscia. There were only eleven records for all other taxa combined (Pseudodiploexochus, Pseudolaureola & Buddelundia) with never more than two for any one taxon. A t-test performed on arcsine-transformed data, tested for homogeneity of variances ($F = 1.048$, $df = 24$ & 19, $p = 0.465$), showed a statistically significant difference in moisture content ($t = 3.08$, $df = 43$, $p = 0.002$). The xeric B. nitidissima was found in the log of the lowest moisture (10.3%). Styloniscus species 6, found at only two sites within the jarrah forest, represented one of the few species confined to logs. It was found in a log with 71.5% moisture content, among the top five moist logs throughout the entire region. Styloniscus species 1, species 7 and Spherillo species 5 were also found in association with this log. Logs of this moisture content outside of the wettest karri forest are very rarely encountered.

The occurrence of taxa found under logs did not appear related to the moisture content or any other properties of the soil. Other factors such as the size and decay state of logs or, as shown by Hornung and Warburg (1996), their distribution and quantity, may be important here. Logs may be shelter refuges for nocturnally mobile taxa whose presence may be related to other site factors. The occurrence of some taxa under logs may also be the surface expression of an endogean existence. All these hypotheses merit further investigation but were beyond the scope of the present study.

7.4. LITTER PROPERTIES

Just as rainfall is important at the regional, litter moisture is an important determinant of the distribution of taxa at the microhabitat scale. Table 7.2 shows a correlation matrix for the microhabitat data of litter samples occurring on soil. It includes all zones but only the variables for which relationships were found. In all the following analyses, duplicate records (i.e. where more than one taxa was found) were removed. Perhaps surprisingly, litter moisture was weakly negatively correlated with density ($r = -0.24$, $p < 0.01$). This may be because thinner or sparser litter is more easily saturated by rainfall than thicker litter. Litter density is more strongly correlated to the weight of fine litter ($r = 0.95$ $p < 0.001$) than it is with the coarse ($r = 0.59$, $p < 0.001$) or medium ($r = 0.65$, $p < 0.001$) fraction. Importantly, only the fine litter fraction was statistically negatively correlated ($r = -0.27$, $p < 0.001$) with litter moisture. To a large extent, these relationships represent a wetter phase of the year and it is not clear how litter moisture relates to litter density in a drier phase. Litter with a denser finer fraction is probably older and more decomposed. It may be that the fine litter fraction resists rehydration due to the production of hydrophobic compounds once it has dried. This may be exacerbated if the litter had passed through a number of wetter and drying cycles. In Western Australian sandy soils, higher organic

matter is known to increase water repellency (McKissock et al. 1998; McKissock, Gilkes & van Bronswijk, 2003)

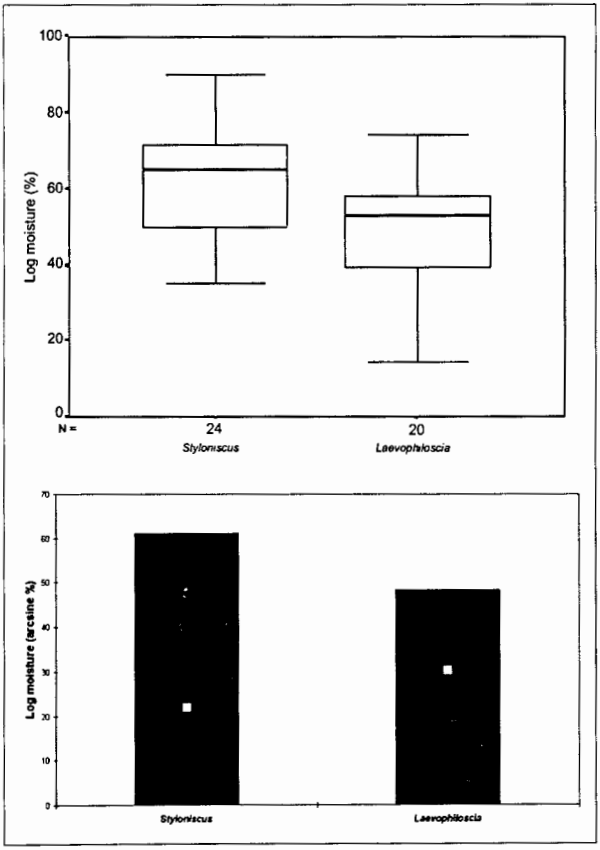


Figure 7.6. A boxplot showing the moisture content of logs (%) and a bar graph showing mean moisture content of logs (arcsine %) with coefficient of variation (squares) for Styloniscus and Laevophiloscia occurring in logs.

Table 7.2
Correlation matrix of microhabitat data for leaf litter with accompanying soil samples. Data are for all zones combined.

	LITTER PROPERTIES				SOIL PROPERTIES					
n = 169	Moisture(% WGT) †	Density (Kg/m^2)	Fine (Kg/m^2)	Medium (Kg/m^2)	Coarse (Kg/m^2)	Moisture (% WGT) †	EC (ms/cm^{-1})	pH	Ca (ppm) †	Organic C (% LOI) †
Litter moisture (%) †	X	-0.24 **	-0.27 ***	-0.14 NS	0.06 NS	0.56 ***	0.23 **	-0.15 NS	-0.04 NS	0.28 ***
Litter density (Kg/m^2)		X	0.95 ***	0.65 ***	0.59 ***	-0 15 NS	-0.07 NS	0.03 NS	-0.10 NS	-0.13 NS
Fine litter (Kg/m^2)			X	X	X	-0.16 *	-0.09 NS	0.08 NS	-0.07 NS	-0.20 *
Medium litter (Kg/m^2)			X	X	X	-0.10 NS	-0.08 NS	-0.14 NS	-0.09 NS	0.16 *
Coarse litter (Kg/m^2)			X	X	X	-0.02 NS	0.10 NS	-0.01 NS	-0.16 *	0.01 NS
Soil moisture (%) †						X	0.41 ***	-0.12 NS	-0.05 NS	0.64 ***
Course sand (% WGT)						-0.08 NS	-0.08 NS	0.11 NS	-0.04 NS	-0.24
Medium sand (% WGT)						-0 08 NS	-0.05 NS	0.23 **	0.59 ***	-0.06 NS
Fine sand (% WGT)						0.13 NS	0.07 NS	-0.11 NS	-0.05 NS	0.25 **
Soil EC (ms/cm^{-1})							X	0 28 ***	0.09 NS	0.24 **
Soil pH								X	0.47 ***	-0.26 ***
Soil Ca (ppm) †									X	-0.06 NS
Soil organic C (% LOI) †										X

NS = Not significant, * = statistically significant, ** = statistically highly significant *** = statistically very highly significant

† = data arcsine transformed and expressed as degrees prior to analysis

The moisture content of the litter is reflected in the moisture content of the soil beneath it. Litter moisture and soil moisture are moderately positively correlated ($r = 0.56$, $p < 0.001$) suggesting that the wetting properties of the litter are transferred to the soil. Soil moisture was most significantly correlated with soil organic content ($r = 0.64$, $p < 0.001$) and will be discussed later in relation to each microhabitat type.

The wetting and drying of litter and soil is influenced by a number of parameters such as the exposure to sunlight, prevailing winds, degree of shading by the canopy and the activity of the decomposer flora and fauna. While none of these were measured during this study, some of the micohabitat utilisation of some taxa has demonstrated the importance of both litter and logs. In most circumstances these microhabitats are not discrete. The spatial distribution of litter build up is influenced by the presence of CWD (Lindenmayer et al., 2002) and the combination of litter and logs plays a valuable role in maintaining ant diversity in managed Australian forests (Andrew, Rodgerson & York, 2000). Litter with logs was an important microhabitat component for the more widely distributed regional and forest taxa and may provide for a greater moisture gradient than either litter or logs on their own. This relationship may extend into drier periods providing for significant moist refuge. The moisture properties of both litter on its own and litter in association with logs for zones are shown in Figure 7.7.

It appears that in the wetter zones, litter with logs becomes moister than litter away from logs. In the drier northern forest and coastal areas, litter with logs is actually less moist than litter occurring on its own. This is reversed in the largest forest zone, Zone 4, where litter with logs becomes moister. It is moister still in the wetter forest Zones 5 and 6 and in the wettest forest zone, Zone 9. In Zone 9, litter with logs is statistically significantly moister than litter occurring on its own. A t-test performed on arcsine-transformed data with homogeneous variances ($F = 2.272$, $df = 18$ & 6, $p = 0.158$) showed a statistically significant difference ($t = -2.538$, $df = 27$, $p = 0.0172$). The results are interesting because litter with logs was a much more utilised microhabitat in wet zones than in the drier north. Of the twelve taxa contributing to northern patterns, only three records came from litter with logs.

Litter density is much greater with logs in Zones 1, 2 and 3. However, caution must be exercised with these data since the data are derived from eleven samples with an outlier of 45.13%. Removing this would reduce the mean to 12.11 kg/m^2 instead of the 15.11% shown in Figure 7.7. The relatively few samples are also a reflection of the fact that this was not a prominent microhabitat in these zones. It is worthwhile including it here, since density appeared to be negatively associated with moisture, and because there are important differences in Zone 3 which will be discussed later.

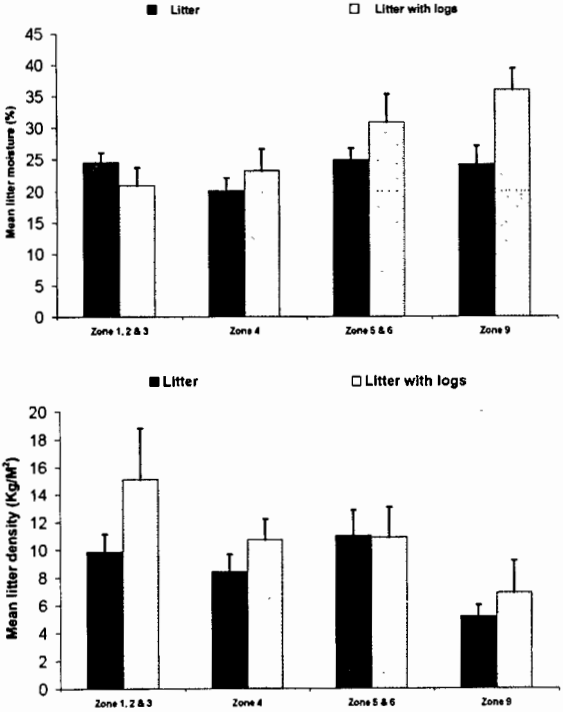


Figure 7.7. Mean litter moisture content (upper) and density (lower) with standard error bars of litter occurring with logs and on its own. There were insufficient data for comparison in zones 7, 8 and 10.

7.5. MICROHABITAT PROPERTIES INFLUENCING MOISTURE

It is clear that moisture is the key to the persistence of many taxa. This section examines the relationships between moisture and other variables. To some extent, this will vary according to local conditions and recent rainfall events. However, the degree to which litter decomposition has been occurring at the micro-scale will be evident in the soil in the form of soil organic carbon. This section examines all of the litter and soil data, and soil sample data from under logs. Table 7.3 expands upon Table 7.2 and shows the relationship among the important soil and litter properties for each of the zones. Table 7.4 shows the relationships among soil properties for soil samples in each of the zones where specimens were collected from under logs. In both tables, the very similar wet forest Zones 5 and 6 have been grouped to increase the sample size. For litter samples, with the exception of Zone 7, there are enough data to examine zones individually. For soil under logs there were insufficient data for Zones 7, 8, 9 and 10 and the similar Zones 1 and 2 on the sandy soils of the northern Swan Coastal Plain were grouped to increase sample size.

7.5.1. LITTER AND SOIL RELATIONSHIPS

Data in Table 7.3 shows a moderate or strong positive correlation between soil organic C and soil moisture throughout all zones. The relationship was statistically significant in all zones except Zone 10. Soil organic C is therefore important to soil moisture under litter and the relationship was strongest in the sandy soils of Zone 1 ($r = 0.71$, $p < 0.001$), Zone 2 ($r = 0.81$ $p < 0.001$) and Zone 8 ($r = 0.89$, $p < 0.001$).

The relationship between litter moisture and soil moisture is variable among the Zones. It is statistically significant in all zones except for Zone 2 and the wet forest Zones 5 and 7. Differences in moisture of litter occurring with logs were shown earlier for Zones 1, 2 and 3, and variability in litter moisture was also noted by Majer (1984) who found that litter moisture was inherently more variable than soil moisture in jarrah forest plots. Zone 3 is the only zone where litter density was statistically significantly negatively correlated with litter moisture ($r = -0.48$, $p < 0.05$). The relationship is also significant for the fine ($r = -0.40$, $p < 0.05$) and medium ($r -0.48$, $p < 0.05$) litter fractions. Both soil moisture ($r = -0.47$, $p < 0.05$) and soil organic C ($r = -0.40$, $p < 0.05$) are negative correlated with litter density in this zone and no others. Therefore, it appears that relationship between litter and moisture is fundamentally different in this zone. It has been argued earlier that terrestrial isopods occurring in this zone rely less on surface organic matter and more upon geomorphological features and soil properties. Zone 3 is rocky with less expansive forest cover and is seasonally very dry. Litter here is exposed to a longer period of drying and has less time for moisture to drive the decomposition cycle. Whilst fresher, less dense litter may wet easily, litter that has accumulated becomes deeper and may have passed through a number of wetting and drying cycles, developing hydrophobic

characteristics discussed previously. Inferences from the data are made based only on the presence of isopods however and therefore should be cautious.

Table 7.3
Correlation matrix of selected soil and litter data, analysed in relation to each zone, for litter samples occurring on soil

Zone (n)		LITTER PROPERTIES					SOIL
		Moisture (%) †	Density (Kg/m2)	Fine (Kg)	Medium (Kg)	Coarse (Kg)	Moisture (%) †
1 (24)	Litter density (Kg/m2)	-0.22 NS	X				
	Fine litter (Kg)	-0.26 NS	0.98 ***	X			
	Medium litter (Kg)	0.01 NS	0.54 **	X	X		
	Coarse litter (Kg)	0.29 NS	0.29 NS	X	X	X	
	Soil moisture (%) †	0.69 ***	-0.16 NS	-0.16 NS	-0.15 NS	0.06 NS	X
	Soil organic C (LOI%) †	0.50 **	-0.17 NS	-0.19 NS	0.08 NS	0.07 NS	0.71 ***
2 (16)	Litter density (Kg/m2)	-0.07 NS	X				
	Fine litter (Kg)	-0.25 NS	0.86 ***	X			
	Medium litter (Kg)	-0.07 NS	0.68 **	X	X		
	Coarse litter (Kg)	0.34 NS	0.70 **	X	X	X	
	Soil moisture (%) †	0.43 NS	0.11 NS	0.05 NS	0.00 NS	0.19 NS	X
	Soil organics (LOI%) †	0.44 NS	-0.14 NS	-0.21 NS	-0.04 NS	-0.02 NS	0.81 ***
3 (25)	Litter density (Kg/m2)	-0.48 *	X				
	Fine litter (Kg)	-0.40 *	0.95 ***	X			
	Medium litter (Kg)	-0.48 *	0.71 ***	X	X		
	Coarse litter (Kg)	-0.27 NS	0.57 **	X	X	X	
	Soil moisture (%) †	0.55 **	-0.47 *	-0.41 *	-0.42 *	-0.27 NS	X
	Soil organic C (LOI%) †	0.02 NS	-0.40 *	-0.40 *	-0.14 NS	-0.37 NS	0.48 *
4 (39)	Litter density (Kg/m2)	-0.05 NS	X				
	Fine litter (Kg)	-0.15 NS	0.93 ***	X			
	Medium litter (Kg)	-0.03 NS	0.75 ***	X	X		
	Coarse litter (Kg)	0.19 NS	0.76 ***	X	X	X	
	Soil moisture (%) †	0.54 ***	-0.02 NS	-0.05 NS	0.06 NS	-0.02 NS	X
	Soil organic C (LOI%) †	0.28 NS	-0.02 NS	-0.06 NS	0.25 NS	-0.12 NS	0.69 ***
5 & 6 (19)	Litter density (Kg/m2)	-0.32 NS	X				
	Fine litter (Kg)	-0.28 NS	0.85 ***	X			
	Medium litter (Kg)	-0.34 NS	0.87 ***	X	X		
	Coarse litter (Kg)	-0.10 NS	0.81 ***	X	X	X	
	Soil moisture (%) †	0.18 NS	-0.16 NS	-0.06 NS	-0.23 NS	-0.15 NS	X
	Soil organic C (LOI%) †	-0.18 NS	0.24 NS	-0.09 NS	0.49 *	0.41 NS	0.46 *
8 (9)	Litter density (Kg/m2)	-0.37 NS	X				
	Fine litter (Kg)	-0.42 NS	0.99 ***	X			
	Medium litter (Kg)	-0.31 NS	0.97 ***	X	X		
	Coarse litter (Kg)	0.09 NS	0.75 **	X	X	X	
	Soil moisture (%) †	0.91 ***	-0.41 NS	-0.44 NS	-0.35 NS	0.00 NS	X
	Soil organic C (LOI%) †	0.78 **	-0.57 NS	-0.61 *	-0.53 NS	-0.10 NS	0.89 ***
9 (28)	Litter density (Kg/m2)	-0.16 NS	X				
	Fine litter (Kg)	-0.16 NS	0.98 ***	X			
	Medium litter (Kg)	-0.16 NS	0.74 ***	X	X		
	Coarse litter (Kg)	-0.06 NS	0.63 ***	X	X	X	
	Soil moisture (%) †	0.80 ***	-0.23 NS	-0.20 NS	-0.29 NS	-0.21 NS	X
	Soil organic C (LOI%) †	0.36 NS	-0.14 NS	-0.18 NS	0.05 NS	0.10 NS	0.58 ***
10 (9)	Litter density (Kg/m2)	-0.24 NS	X				
	Fine litter (Kg)	-0.18 NS	0.99 ***	X			
	Medium litter (Kg)	-0.33 NS	0.61 *	X	X		
	Coarse litter (Kg)	-0.26 NS	0.64 *	X	X	X	
	Soil moisture (%) †	0.79 **	-0.30 NS	-0.25 NS	-0.18 NS	-0.39 NS	X
	Soil organic C (LOI%) †	0.35 NS	-0.31 NS	-0.33 NS	0.27 NS	-0.42 NS	0.55 NS

NS = Not significant; * = statistically significant; ** = statistically highly significant *** = statistically very highly significant
† = data arcsine transformed and expressed as degrees prior to analysis.

7.5.2. LOG AND SOIL RELATIONSHIPS

The data for soil under logs given in Table 7.4 and Zone 3 soil data is again notable as it shows similar characteristics to soil under litter. The correlation between soil organic C and soil moisture ($r = 0.41$, $p < 0.05$), although statistically significant, is much weaker than other zones, The fine sand content of the soil shows the strongest relationship with soil moisture ($r = 0.74$, $p < 0.001$). Fine sand shows statistically significant positive correlations with soil moisture in all zones except Zone 4 but only in Zone 3 is it stronger than the correlation with soil organic C. Similarly, the amount of coarse sand has a statistically significant negative correlation with soil moisture in all zones. Fine sand not only has the potential to store more water through its finer texture but also reduces water repellency (McKissock et al., 1998).

Again, the most consistent relationship overall was between soil moisture and soil organic C. There was a statistically significant relationship both under litter and under logs, overall and for individual or grouped zones. Figures 7.8 and 7.9 present these relationships graphically.

7.5.3. SOIL PROPERTIES

As well as relationships between moisture and organic carbon, there are consistent but zonally differing relationships among other soil properties. Looking at all zones combined, both soil covered by litter (Table 7.2) and logs (Table 7.4) showed a statistically significant correlation between soil moisture and soil EC. For soil covered by litter there was a statistically significant relationship between EC and litter moisture ($r = 0.23$, $p < 0.001$), organic C ($r = 0.24$, $p < 0.01$) and pH ($r = 0.28$, $p < 0.05$). Under logs, soil EC is correlated with fine sand ($r = 0.43$, $p < 0.001$). Soil calcium was correlated with the percentage of medium sand in all situations (litter $r = 0.59$, $p < 0.001$; logs $r = 0.73$, $p < 0.001$) and appears unrelated to any other factors. There was an obvious positive and very highly statistically significant relationship between soil calcium content and pH. Soil pH was also influenced by the organic C of soil under litter, because it is weakly negatively correlated with soil organic matter ($r = -0.26$, $p < 0.001$).

The above relationships suggest that moister soils with a higher organic C component, particularly with a high fine sand content, may resist leaching. The nutrients of jarrah forest litter have been described by O'Connell, Grove and Dimmock (1978) and karri forest by O'Connell (1988) and include, amongst others, the elements Na, Cl, K, S, Ca, N and P. It seems that moist conditions promote both the breakdown of organic matter (Woods & Raison, 1983: Ward, Majer & O'Connell, 1991) and the retention of these nutrients within the upper soil profile. This may be also related to the wetting characteristics of the litter.

Table 7.4
Correlation matrix of soil data, analysed in relation to each zone, for samples taken from under logs

Zones (n)		SOIL PROPERTIES				
		Soil moisture (%) †	EC (ms/cm-1)	pH	Soil Ca (ppm) †	Organic C (% LOI) †
All (73)	Soil moisture (%) †	X	0.68 ***	0.14 NS	-0.09 NS	0.69 ***
	Course sand (% WGT)	-0.39 ***	-0.25 *	0.09 NS	0.12 NS	-0.34 **
	Medium sand (% WGT)	0.07 NS	0.13 NS	0.39 ***	0.73 ***	0.02 NS
	Fine sand (% WGT)	0.47 ***	0.43 ***	0.11 NS	-0.15 NS	0.24 *
	Soil EC (ms/cm-1)		X	0.31 **	-0.02 NS	0.09 NS
	Soil pH			X	0.57 ***	-0.06 NS
	Soil Ca (ppm) †				X	-0.12 NS
	Soil organic C (% LOI) †					X
1 & 2 (13)	Soil moisture (%) †	X	0.43 NS	0.03 NS	0.28 NS	0.68 **
	Course sand (% WGT)	-0.56 *	0.18 NS	0.09 NS	-0.49 NS	-0.30 NS
	Medium sand (% WGT)	0.27 NS	0.35 NS	0.73 **	0.99 ***	0.53 *
	Fine sand (% WGT)	0.60 *	0.20 NS	0.29 NS	0.68 **	0.46 NS
	Soil EC (ms/cm-1)		X	0.69	0.32 NS	0.78 ***
	Soil pH			X	0.70 **	0.49 NS
	Soil Ca (ppm) †				X	0.51 NS
	Soil organic C (% LOI) †					X
3 (25)	Soil moisture (%) †	X	0.67 ***	0.62 ***	0.39 *	0.41 *
	Course sand (% WGT)	-0.75 ***	-0.44 *	-0.56 **	-0.22 NS	-0.20 NS
	Medium sand (% WGT)	0.09 NS	0.26 NS	0.08 NS	0.03 NS	-0.05 NS
	Fine sand (% WGT)	0.74 ***	0.54 **	0.50 **	0.26 NS	0.23 NS
	Soil EC (ms/cm-1)		X	0.30 NS	-0.17 NS	-0.05 NS
	Soil pH			X	0.43 NS	0.28 NS
	Soil Ca (ppm) †				X	0.71 ***
	Soil organic C (% LOI) †					X
4 (19)	Soil moisture (%) †	X	0.64 **	0.42 NS	0.16 NS	0.56 **
	Course sand (% WGT)	-0.50 *	-0.29 NS	-0.76 ***	-0.32 NS	-0.24 NS
	Medium sand (% WGT)	-0.20 NS	0.07 NS	-0.01 NS	-0.48 *	-0.22 NS
	Fine sand (% WGT)	0.33 NS	0.37 NS	0.68 ***	0.07 NS	0.15 NS
	Soil EC (ms/cm-1)		X	0.53 *	0.39 NS	0.77 ***
	Soil pH			X	0.58 **	0.36 NS
	Soil Ca (ppm) †				X	0.69 ***
	Soil organic C (% LOI) †					X
5 & 6 (11)	Soil moisture (%) †	X	0.89 ***	-0.01 NS	0.60 *	0.95 ***
	Course sand (% WGT)	-0.72 **	-0.80 **	0.39 NS	-0.01 NS	-0.50 NS
	Medium sand (% WGT)	0.31 NS	0.47 NS	-0.59 *	-0.15 NS	-0.24 NS
	Fine sand (% WGT)	0.56 *	0.60 *	-0.62 *	-0.18 NS	0.16 NS
	Soil EC (ms/cm-1)		X	-0.19 NS	0.50 NS	0.92 ***
	Soil pH			X	0.65 *	0.19 NS
	Soil Ca (ppm) †				X	0.74 **
	Soil organic C (% LOI) †					X

NS = Not significant; * = statistically significant; ** = statistically highly significant *** = statistically very highly significant
† = data arcsine transformed and expressed as degrees prior to analysis.

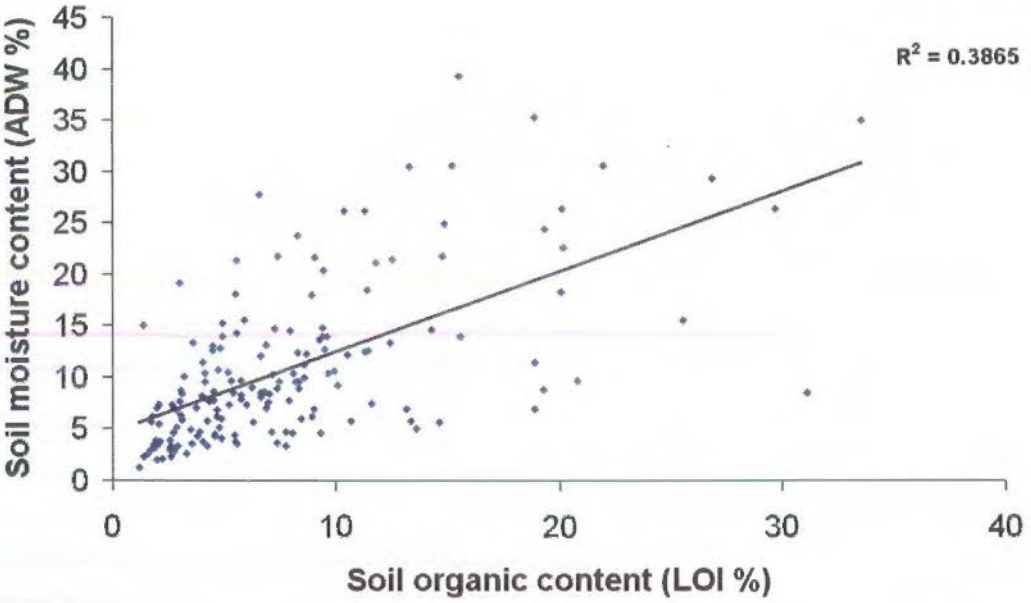


Figure 7.8. The relationship between soil organic C and soil moisture under leaf litter. Data for both axes are arcsine transformed.

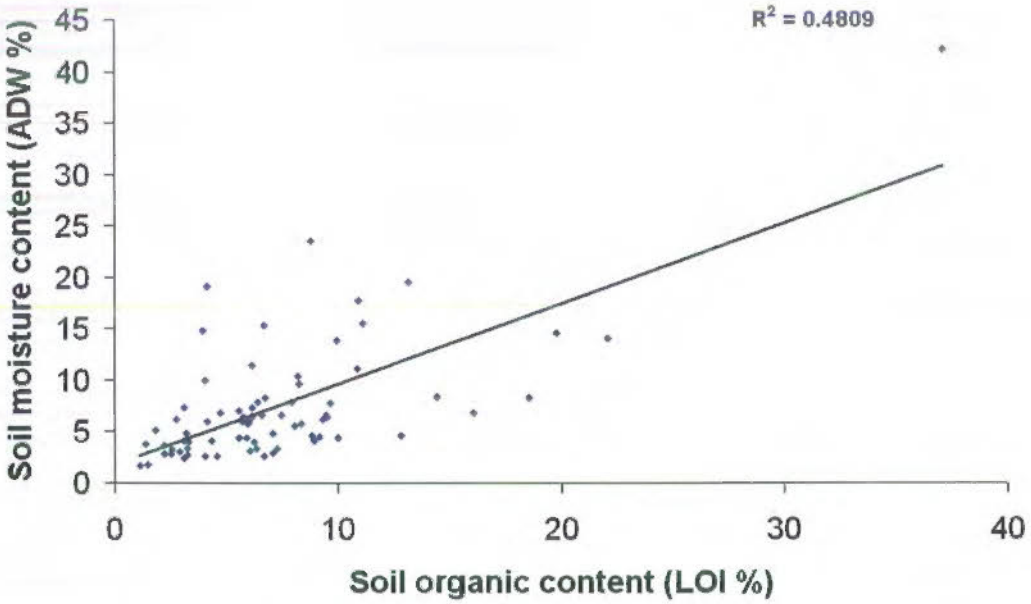


Figure 7.9. The relationship between soil organic C and soil moisture under logs. Data for both axes are arcsine transformed.

Zone 3 appears markedly different from the others in its surface organic characteristics. There appear also to be subtle differences in the surface organics characteristics of the other forest zones. Zones 5 and 6, which represent the wetter jarrah forest, showed distinctly different patterns in the relationships between organic matter and soil moisture under litter compared to under logs. For soil under litter, the correlation coefficient was 0.46 ($p < 0.05$) (Table 7.3), the lowest for any zone and for soil under logs it was 0.95 ($p < 0.001$) (Table 7.4) the highest for any zone. These observations are interesting because Zones 5 and 6 were the only zones not to display a statistically significant positive correlation between soil moisture and litter moisture. It may be true, for the time of sampling, that in the wetter forest zones moisture conditions are less reliant on surface organics due to higher and more reliable rainfall. In fact, wetting in open situations may occur much more easily and evenly compared to Zone 3. However, soil under logs may stay drier than surrounding litter. In this case, organic C content may well have a much greater influence upon soil moisture. Conditions under logs in wetter forests would remain damp for much longer than in drier areas or in surrounding litter and so moisture-driven decomposition would occur for longer, thus contributing more organic matter to the soil. The influence of leaching may also be less, and this may be indicated by the fact that soil moisture under logs in Zones 5 and 6 displayed the strongest relationships with both soil EC (Table 7.4, $r = 0.89$, $p < 0.001$) and soil calcium content (Table 7.4, $r = 0.60$, $p < 0.05$).

In the large forest Zone 4, a zone without endemic taxa, mean litter moisture was nearly 5% less than in other forest zones, and soil moisture was related to litter moisture in a similar manner to Zone 3. Soil moisture was strongly correlated with soil organic C, more so than in any other forest zone. Unlike Zone 3 however, soil moisture under logs was not positively correlated to fine sand, only negatively correlated to the percentage of coarse sand (Table 7.4 $r = -050$, $p < 0.05$). It may be that Zone 4 is becoming drier and more like Zone 3 in its surface organic characteristics. However, it has neither the variety of landform to provide for the range of microhabitat opportunities nor the taxa adapted to them. As was indicated by the biogeographical patterns in Chapter 4, endemism in the southern half of the jarrah forest bioregion is confined to two relatively small zones of high rainfall jarrah forest and is dependent on surface organic matter.

Zone 9, encompassing most of the karri forests, which have been shown to produce rates of litterfall among the highest for Australian forests (O'Connell & Menagé, 1982), was notable for its less dense litter (Figure 7.6). Rates of decomposition are also high (O'Connell, 1987) thereby reducing litter densities considerably. In the wetter and cooler Zone 9, litter stays moister for longer, thereby promoting a longer period of invertebrate activity (Majer & Abbott, 1989) and therefore decomposition. There were very few taxa collected from under logs in Zone 9. The moister environment tended to favour other microhabitats. Logs were also much larger in zone 9 and the underside much more integrated with mineral substrate. Logs also appeared to influence greatly the drying of

litter. Litter next to logs in Zone 9 remained moister than litter occurring away from logs and was the moistest litter found anywhere in the region (Figure 7.6).

7.6 ORGANIC MATTER, MOISTURE AND TERRESTRIAL ISOPODS

Among the most prominent genera of terrestrial isopods in Western Australia there is evidence of differing tolerances to different moisture conditions. The dependence upon different moisture levels was demonstrated in a range of microhabitats, and the results were remarkably consistent. In the Styloniscus and Buddelundia in particular, not only were there adaptations to remarkably different moisture regimes but also preliminary evidence of moisture differentiation by different species. The point-scale distribution of many species is linked to the provision of moist microhabitat, not only during the wetter season when this study was conducted, but also probably to patterns of wetting and drying throughout the year. There were relationships between soil organic matter and soil moisture suggesting that not only is decomposition likely to be driven by moisture, but also that the product of decomposition is likely to influence moisture. Therefore, the presence of terrestrial isopods is fundamentaliy part of, and linked to, processes of organic decomposition.

There were differing relationships among soil and litter variables within the zones identified in the previous chapter. Perhaps the most stark difference was that of Zone 3 in the northern Jarrah Forest Bioregion. This is the richest zone and one in which the species composition can change over relatively short distances. In this zone, the nature of surface organic matter was different. It was hypothesised that patterns of wetting and drying may be different in this zone, a feature that would explain the lesser dependence of taxa upon organic matter, an increased utilisation of logs and soil, and ultimately perhaps, a more diverse fauna.

There were also some differences between the surface organic matter properties of coastal zones and forest zones possibly representing differences in the underlying soil type. The starkest difference was between the most species rich northern forest Zone 3 and the far southern Zone 9. Zone 9 was much wetter, had less dense litter, suggesting more decomposition, and was uniformly moister due to higher and more consistent rainfall. This zone is also species rich but for fundamentally different reasons. Greater moisture, higher productivity and regular decomposition allowed for a rich and endemic terrestrial isopod fauna relying almost entirely upon surface organic matter. There were elements of these fauna in Zones 5 and 6 in the jarrah forest where the nature surface organic matter differed subtly from the larger jarrah forest Zone 4.

The relative dependency upon moisture of the genera investigated paralleled their geographical ranges. The most restricted forest taxa such as Pseudolaureola, which were shown in Chapter 5 to be confined by high rainfall, were also the most dependent upon moisture. The most widely distributed forest taxa, such as Buddelundia nitidissima and Spherillo species 5 were capable of inhabiting much drier litter. This suggests that

both the nature and distribution of surface organic matter have been an important evolutionary force upon the terrestrial isopods in south-western Australia. This hypothesis will be developed in the next chapter. However, before this can take place, the present day importance of surface organic matter is discussed in the light of the available literature.

7.7. DISCUSSION

The moisture retaining capacity of both litter and CWD are important to the provision of microhabitat. Decomposition cycles in Australian forests are driven by the seasonal inputs of litter and availability of moisture (Woods & Raison, 1983; Hutson & Veitch, 1985). In wetter parts of the forests of south-western Australia, short-range endemism of terrestrial isopods is related to the availability of a sufficiently moist substrate, and long-term accrual of organic matter is an important buffer against seasonal dryness. In fact, the southern forest region of Western Australia is characterised by relictual biota highly dependent upon fine scale hydrological regimes (Wardell-Johnson & Horwitz, 1996) many of which are maintained by the accumulation of the organic matter (Horwitz, Judd & Sommer, 2003). Anything that disrupts the spatial and temporal distribution of organic matter is therefore likely to affect terrestrial isopods.

A heterogeneous forest floor contains pockets of moisture where decomposition can proceed for longer into the drier period, and litter decomposition is likely to be enhanced by favourable by changes in microclimate (Ward, Majer & O'Connell, 1991). The build up of organic matter also helps to retain moisture, therefore creating a cycle of moisture-dependent decay. In seasonally dry climates, soil temperatures in inter-canopy patches are much higher and dry much more quickly in summer than areas shaded by canopy. In winter, the opposite occurs. Canopy patches can have higher temperatures due to the lower solar angle, and insulation of litter dampens the diurnal variance in temperature (Breshears et al.,1998). Shading is important. It provides for more constant temperature regimes, which favour decomposition, and buffers the decomposer community from climatic extremes. Furthermore, the presence of canopy and trees themselves affects the distribution of moisture on the forest floor.

Logs are also important in retaining moisture as well as possibly insulating litter from the processes of drying. The slow rate of log decomposition, particularly of large logs, in Western Australian forests means that they act as carbon sink for many decades (Brown et al., 1996). As well as storing carbon, logs in the wettest situations under a closed canopy can actually increase their moisture content over time (Brown et al., 1996). Large logs have higher moisture content than smaller logs, and CWD in general provides a favourable moisture balance well into the dry season. So much so that Brown et al. (1995, p. 965 emphasis added) suggested that "the presence of *large, moist* logs has the potential to enhance and (or) maintain the biodiversity of the decomposer food web."

Terrestrial isopods are, if not the most abundant decomposers, an extremely significant component part of forest biodiversity.

The biogeographic model showed a distinct difference in the microhabitat utilisation of the north of the region. Northern taxa formed some of the clearest patterns and showed less dependence on organic matter. In the open forests and woodlands of this part of the region with an extended drier period, there is less possibility of both litter and logs remaining moist into the dry season. Rocks and rocky biotypes have been identified as important contributors to microhabitat. In a similar way to logs, rock outcrops can influence the build up of surface organic matter and influence the flow of surface water (Main, 2000). Stone cover also has a profound effect on the conservation of soil moisture in Mediterranean climates, both by reducing capillary action and by lowering soil temperature (Pérez, 1998).

Drying decreases the availability of moist microhabitats, slows decomposition rates and reduces the build up of organic matter in the soil. Western Australian forests are subject to intense and broad scale management techniques (Wardell-Johnson & Horwitz, 2000) and there has been a long history of timber extraction. Most of the jarrah forest has been already cut at least once (Heberle, 1997; Calver & Dell, 1998a). Prescription burning is also undertaken to limit the intensity of unplanned fires by fuel loads to levels that facilitate fire suppression and therefore prevent "physical damage" to the forest (McCaw, Neal & Smith, 1996).

7.7.1. TIMBER EXTRACTION

Timber extraction is potentially detrimental to distribution and abundance of terrestrial isopods, because it removes carbon and dries the forest. Timber extraction creates more CWD (Watson, in prep) with an artificial spatial and size distribution, and a notable reduction in large size classes (Grove, 2001). It also removes canopy cover, many large trees and consequently, potentially sizeable logs from the forest. Lindenmayer et al. (1999) pointed out that intensive human disturbance in mountain ash forest in eastern Australia will limit the recruitment of large diameter logs onto the forest floor.

The amount of organic carbon in the soil is greatly influenced by site disturbance (O'Connell, 1987). In a pioneering study, Wallace and Hatch (1952) showed that soil organic carbon, as a percentage of oven-dry weight, in pole and sapling jarrah forest blocks was nearly half that in virgin forest. Furthermore, they demonstrated that the cation exchange capacity of the lateritic sandy soils, typical of much of the jarrah forest, was closely related to amount of organic matter within the soil. When studying comparable areas of forest in which jarrah trees had died, and litter inputs came from understorey shrubs, soil organic carbon declined further (Wallace and Hatch, 1952). A positive relationship between tree size (basal area) and litter accession to the forest floor was shown by findings of Turnbull and Madden (1983). Therefore, soil organic carbon is probably affected by the density and age of the jarrah tree themselves. Reduced inputs

of organic matter through reduced litterfall, slower rates of surface breakdown and increased rates of microbial mineralization of soil organic matter, contribute significantly to the depletion of organic C in disturbed forest soils. The consequence of these processes is to reduce the capacity of the forest floor to retain moisture. Therefore, logging results in moisture deficits and restricted decomposer activity. This is further exacerbated by the mixing of surface organic matter and subsoil during logging operations, reduced shading, resulting in higher soil temperatures and the rapid drying of leaf litter in exposed localities following rainfall (O'Connell, 1987). Studies elsewhere in the world (Liechty, Holmes, Reed & Mroz, 1992), and in less extreme climates, have shown that, in forests subject to timber extraction, air and soil temperatures as well as soil moisture content, showed no indication of recovery to levels shown in undisturbed plots during the five years of the study.

7.7.2. FIRE

Fire, depending on the season and source of ignition, can periodically result in the complete ashing of the litter layer and exposure of mineral substrate (O'Connell et al., 1979) thus completely ceasing litter breakdown for a period of time. The degree to which soil organic matter is oxidised depends upon the temperatures generated by the fire, fire duration and heat penetration (Choromanska & DeLuca, 2002). Soils exposed to intense fire have been shown to have less water retention capacity than comparable unburnt soils (Fayos, 1997). Majer (1984) showed that burning can influence soil moisture and temperature, litter moisture and relative humidity within forested areas. The potential effect of fire upon microhabitat is illustrated by the fact that changes in soil temperature showed a marked increase following a burn. The soil remained warmest in the burnt plots, and relative humidity was lower following a burn. Litter quantities were understandably lower following a fire and, while litter moisture content generally reflected rainfall, it showed much greater variability than soil moisture. In Majer's (1984) study, terrestrial isopod numbers showed a strong seasonal trend toward the wetter months of July-October. They were very much higher in the unburnt plot and isopods were collected predominantly from litter samples rather than soil samples. Both reduction in soil moisture retention following fire, and changes in litter depth and distribution have also been shown to be important in determining the distribution of hypogeous fungi within Australian forests (Claridge et al., 2000).

Fires also affect leaf litter inputs. O'Connell et al. (1979) showed that litterfall doubled in a burnt locality compared to an unburnt locality in the first year following a fire, and accession of scorched leaves following a fire was also noted by Majer (1984). In organic-rich soils, vegetation fires can decrease the rate of water infiltration due to ash particles clogging soil pores in but can lead to greater water retention upper layer (Mallik, Gimingham & Rahman, 1984) and result in profound structural and physico-chemical changes (Horwitz et al., 2003). Abbott, van Heurk and Wong (1984) found soil moisture to be considerably greater in an unburned stand of jarrah forest than in a burned stand.

However, their results focused on the relative increase nutrients in the burned stand and this result was not explained.

Differences in litter quantities between burned and unburned stands are often masked by inherent spatial patchiness in leaf litter (e.g. Abbott et al., 1984). The same is therefore true for invertebrate communities, both spatially, and also when there is strongly seasonal activity (Collet, 1999). Nevertheless, Springett (1976) demonstrated marked changes in the composition of litter-dwelling invertebrate communities following fire in two forest types In this paper, and a subsequent one (Springett, 1979), she noted that terrestrial isopods were absent from recently burnt localities in the jarrah forest and reduced in numbers in the wetter karri forest. While this is to be expected, particularly after hot summer or autumn fires, Springett (1976) suggested the recovery period for terrestrial invertebrate communities was longer than the interval between prescribed fires.

Collet, Neumann and Tolhurst (1993) and Collet (1999) recorded nearly an third less terrestrial isopods in a burnt plot of dry sclerophyll forest compared to an unburnt control. Unfortunately, an ordinal level analysis in this study precludes any assessment of the types of terrestrial isopods trapped by either study. Similarly, Majer (1984) noted a decrease in isopod activity following a cool burn in jarrah forest; peak in winter activity was much less in a burnt plot following a fire than in an unburnt control.

7.7.3. SYNTHESIS

This review of the literature suggests that there is likely to be a synergistic effect of timber extraction and prescribed burning. Both activities promote a drying of the landscape and a reduction in the decomposition coefficient of forest systems. The use of machinery in timber extraction can result in detectable differences in the upper soil profile in bulk density, macro- and micro-porosity and a reduction in saturated hydraulic conductivity (Incerti, Clinnick & Willatt, 1987). Wronski (1984) demonstrated significant compaction of the A soil horizon following logging operations in karri forest near Pemberton in Western Australia.

Moisture and O and A horizon depth were found by Marra and Edmonds (1998) to be most important quantitative factors affecting arthropod communities, and they suggested that clear cutting reduces the abundance and diversity of soil arthropods primarily by reducing organic matter, and by increasing temperature and moisture extremes beyond the tolerance of most arthropods. Since terrestrial isopods are moisture-dependent, the removal of shading, changes in litter accession, redistribution of surface and soil organic matter is likely to be reflected in terrestrial isopod communities. Drying will decrease the range of available moist microhabitats. It slows the decomposition rates and reduces the build up of organic matter in the soil. This reduces the potential for edaphic control and buffering of the decomposer community against periodic drought and fire. The drier the landscape becomes, the more dependent it becomes upon fire for the cycling of nutrients. Such a situation would be to the detriment of forest biodiversity and ecological health.

O'Connell Grove and Dimmock (1978) suggested that a reduction in the amount of soil organic C may also diminish the ability of the forest to withstand the plant pathogen Phytophthora cinnamomi. The application of frequent broad-scale management regimes has been to homogenize conditions on the forest floor. In terms of fire, litter fauna takes longer to recover to pre-fire levels than soil fauna and spring burning is thought be more detrimental to the soil fauna than autumn burning (Majer, 1985).

Surface organic matter in Western Australian forests is essential to the conservation of a significant component of regional biodiversity. Furthermore, the diversity of the regions' fauna, their marked associations with differing microhabitats and moisture regimes, and the inherent ecological characteristics of terrestrial isopods in general (Paoletti & Hassall, 1999), suggest that they have potential to act as indicators of changing forest conditions. Their utility in the context of the forests of south-western Australia depends upon further taxonomic review, particularly of the wet forest litter dwellers, and a more detailed knowledge of the relationship between moisture and organic matter throughout different seasons. The fact that high rainfall localities contain pockets of highly restricted, relictual and undescribed species calls for a highly precautionary approach to the manipulation of organic matter. The application of broad scale, frequent and homogeneous fire regimes is not appropriate for the conservation of regional Oniscidea. Changes in the production, decomposition or spatial and temporal distribution of surface organic matter, will affect the distributions of terrestrial isopods. It has probably been central to the evolution of the group within southwestern Australia and must therefore play a part in its conservation.

To determine the extent of the influence of surface organic matter upon the past and present patterns of the terrestrial isopods, the next chapter hypothesises as to the evolutionary history of the terrestrial isopods within the region. It achieves this by evaluating a revised version of the biogeographic model in the light of other biogeographic patterns and models available for the region. The relationships with moisture and organic matter will be evaluated in order to determine how past events have resulted in the biogeographic patterns of fauna found today and to what degree recent anthropogenic disturbance may have superimposed patterns of their own. The chapter will then reflect on the importance of the work to the conservation of biodiversity in the region, and suggest priorities for future investigation.

CHAPTER 8

REGIONAL REFLECTIONS

8.1. OVERVIEW

This chapter provides a synthesis of the information presented so far and, using the terrestrial isopod fauna, reflects upon the region, the way it has come to be, the way it is perceived and ultimately managed for the conservation of its biodiversity. A logical starting place is to evaluate the biogeographic model described in Chapter 6. This is a representation of landscape units in which the biota is likely to be responding to a series of landscape processes in similar ways. The accuracy of this model will ultimately be judged by its concordance with other biogeographical patterns found in the region. If the landscape units are genuine natural regions their boundaries will be detectable in other biota. To this end, a refined version of the model determined in Chapter 6 is presented here. Rather than having the zones constructed from the rigid boundaries of the locality geographical unit as used in other chapters, the region is delineated to provide boundaries based on endemic groups. A series of three hierarchical delineations is made. A prominent biogeographical boundary in the form of a significant faunal break is recognised, dividing the region into two distinct subregions. This is in stark contrast to other divisions so far recognised within the region. This faunal break (the "Main Line") and two further boundaries, the "Nicholls Line" and the "Darling Scarp Line", are drawn within these subregions recognising areas of significant richness and/or parapatry among species. A third series of lines are drawn representing areas at which small-scale endemism is present.

Following the presentation of this model, the concepts of landscape and geographical differentiation are assessed and the model evaluated. The chapter then explores the processes that are likely to have been significant in the evolution of terrestrial isopods in southwestern Australia. These evoloutionary processes will help to explain concordance or otherwise with other biogeographic patterns of the region and will enable the importance of surface organic matter to be evaluated in context. A historical biogeography, together with understanding of the role of organic matter, will not only determine the likely principal causal factors responsible for the fauna we see today but also allow hypotheses to be drawn as to the role that recent exogenous disturbance has had upon the region's terrestrial isopods. Ultimately, in the context of environmental management, we need to understand why the patterns we see today are present and how they are to be maintained. Identifying some of the processes likely to be of concern to the conservation of the region's terrestrial isopods is the logical first step in planning for their conservation.

The aims of this Chapter are therefore to:

- Refine the biogeographic model by presenting a series of hierarchical delineations creating of zones of endemism;
- Reassess landscape differentiation diversity within the biogeographic zones;

- Assess geographical differentiation among the biogeographic zones;
- Determine the likely historical influences upon the evolution of terrestrial isopods in the region;
- Evaluate the likely importance of the role of surface organic matter in the evolutionary processes identified;
- Develop hypotheses as to how and why the biogeographical patterns came to be; and,
- Consider the degree to which recent patterns have influenced the model, what land practices are likely to have affected, and will continue to affect, the distributional patterns of south-western Australian isopods.

8.2. THE MODEL REVISITED

Chapter 6 presented a biogeographic model showing ten zones named and described by their landscape characteristics. A refined version of that model is presented here. Delineations were made to more accurately reflect the distributions of key individual taxa rather than confining zones to the sharp boundaries of localities. Figure 8.1 shows a hierarchical series of delineations that split the region into consecutively smaller areas. A first order delineation (Figure 8.1A), indicating a major faunal break called the "Main Line", divides the region into two subregions; the Northern (N) and Southern (S). The second order delineation (Figure 8.1B) then splits the Northern Subregion longitudinally into two macrozones (Ne & Nw), while the Southern Subregion is split into a far south macrozone (Ss) and a central macrozone zone (Sn). Finally, based on endemic taxa and the presence of outlying populations of other important taxa, third order delineations (Figure 8.1C) subdivide the macrozones. Table 8 1 gives a list of the taxa detailed in Chapters 4 and 5 and their associations with each zone. Totals show the total number of endemic taxa created by each delineation and number of endemics restricted to each of the subregions, macrozones and zones. Subsections 8.2.1 describes the species whose parapatric range boundaries are concordant with the delineations made in the model. Subsection 8.2.2 describes the species endemic to the zones created. Reference to the relevant distribution maps in Chapter 4 is given where appropriate.

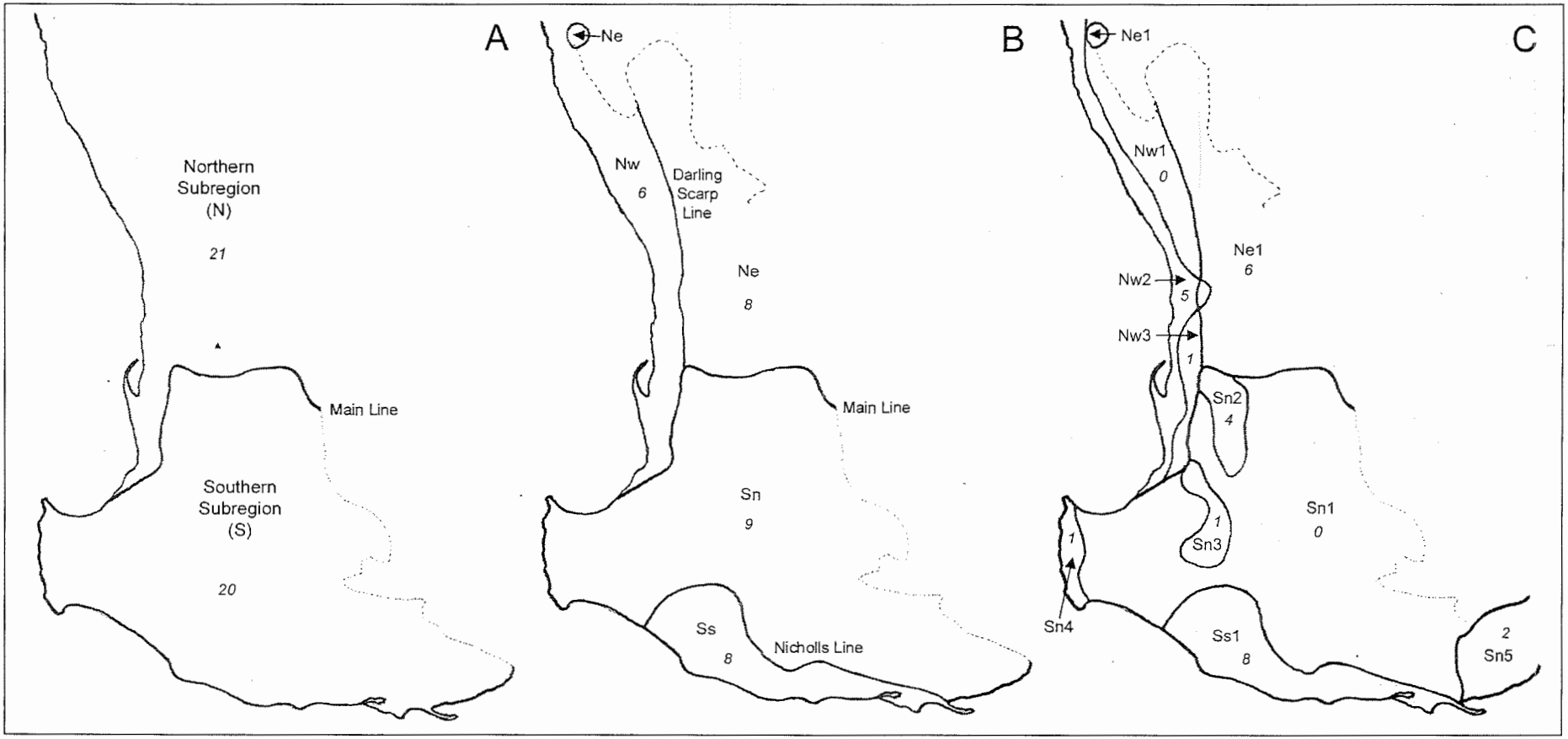


Figure 8.1. Hierarchical biogeographic delineations of the region. One first order delineation (A), the Main Line divides the region into Northern and Southern subregions (N & S). Mt. Cooke (▲) is included in the southern subregion. Two second order delineations (B), the Darling Scarp Line and the Nicholls Line, subdivide the northern subregion into two macro zones (Ne & Nw) and the southern subregion into two macro zones (Sn & Ss). Five third order delineations (C) subdivide macrozone Nw creating Nw1-3 and zone Sn creating zones Sn1-5. The number of endemic taxa is shown in italics and totals are given in Table 8.1. The southeastern boundary of the study area is shown by a dotted line. Area east of this line was included in the northern subregion, macrozone Ne and Zone Ne1. Dashed lines also provide preliminary boundaries in the north of the region. Since many taxa occurred up to the northeast edge of the study area, a true boundary cannot be defined at this stage.

Table 8.1

Endemic taxa created by a series of hierarchical delineations. The first delineation creates subregions that account for endemism in 68% of the taxa, the second create macrozones that account for 52% endemism and the third zones that account for 33% endemism.

Delineation Order	First		Second				Third								
	Subregions		Macrozones				Zones								
Taxon	N	S	Nw	Ne	Sn	Ss	Nw1	Nw2	Nw3	Ne1	Sn1	Sn2	Sn3	Sn4	Sn5
Notoniscus sp. nov.		X				X									
Styloniscus sp. 1															
Styloniscus sp. 2															
Styloniscus sp. 3		X				X									
Styloniscus sp. 4		X			X									X	
Styloniscus sp. 5	X			X						X					
Styloniscus sp. 6															
Styloniscus sp. 7															
Platyarthridae sp. 1															
Platyarthridae sp. 2	X			X						X					
Platyarthridae sp. 3															
Platyarthridae sp. 4	X			X						X					
Australoniscus springetti		X			X										X
Hanoniscus monodi	X														
Hanoniscus nicholisi		X				X									
Hanoniscus tuberculatus	X														
Hanoniscus sp. nov.														P	
Philosciidae sp. 1	X														
Philosciidae sp. 2	X		X					X							
Eurygastor sp. nov.															
Laevophiloscia sp. 1															
Laevophiloscia sp. 2															
Pseudodiploexochus sp. 1															
Pseudodiploexochus sp. 2															
Pseudodiploexochus sp. 3		X			X							X			
Pseudolaureola sp. nov. 1		X			X							X			
Pseudolaureola sp. nov. 2		X				X									
Pseudolaureola wilsmorei		X												O	
Pseudolaureola sp. nov. 3		X				X									
Pseudolaureola sp. nov. 4		X			X										X
Pseudolaureola sp. nov. 5		X			X								X		
Spherillo sp. 1	X			X						X					
Spherillo sp. 2	X														
Spherillo sp. 3		X				X									
Spherillo sp. 4	X			X											
Spherillo sp. 5															
Acanthodillo flavus	X														
Acanthodillo sp. 1															
Acanthodillo sp. 2	P			P											
Acanthodillo sp. 3		X			X							X			
Acanthodillo sp. 4		X				X									
Acanthodillo sp. 5		P													
Cubaris sp. 1	X														
Cubaris sp. 2	X		X					X							
Cubaris sp. 3		X				X									
Cubaris sp. 4		X			X										P
Buddelundia inaequalis	X		X*					X*							
Buddelundia cinerascens	X		X					X							
Buddelundia sp. 1	X		X						X						
Buddelundia sp. 2	X			X											
Buddelundia opaca	X			X						X					
Buddelundia sp. 3	X														
Buddelundia sp. 4	X			X						X					
Buddelundia sp. 5		X			X							X			
Buddelundia sp. 6		X											O	O	O
Buddelundia sp. 7	X		X					X							
Buddelundia nigripes													O	P	
Buddelundia nitidissima															
Buddelundia albomaculata															
Buddelundia sp. 8		X													P
Number of endemics	21	20	6	8	9	8	0	5	1	6	0	4	1	1	2
Number of endemics created by delineation(s)	41 (68%)		31 (52%)							20 (33%)					

Key

X Taxon endemic to Zone. Totals include only these taxa.

P Taxon found principally in that zone but with a single record from an adjacent zone.

O A significant population of the taxon occurs as an outlier in that zone.

* A single outlier with imprecise locality data were excluded from the data set

8.2.1. DELINEATIONS IN RELATION TO THE DISTRIBUTION OF TAXA

The Main Line indicates either the most northerly or southerly occurrence of many species. The southern most distributions of Buddelundia opaca, B. cinerascens (Figure 4.22) Buddelundia species 4 (Figure 4 .20), Spherillo species 2 (Figure 4.19) all end at the Main Line Conversely, the Main Line represents the northern limit of the geographical range of the characteristic high rainfall Buddelundia species 6 (Figure 4 .10) and the genus Pseudolaureola.

The Nicholls Line, which creates a southern macrozone with the southern subregion, mirrors the geographical range of three parapatric taxa, Cubaris species 3, Pseudolaureola new species 3 and Spherillo species 3 (Figure 4.12). Other local and restricted taxa have geographical ranges extending northward only as far as the Main Line. The Darling Scarp Line creates two macrozones in the north of the region. It delineates the eastward parapatric distributions of Spherillo species 2, Buddelundia species 7 (Figure 4.19) and Buddelundia cinerascens (Figure 4.22) and the westward parapatric distributions of Buddelundia species 4 and Spherillo species 4 (Figure 4.20).

The smaller zones created within the four macrozones represent the parapatric boundaries of a range of restricted species, but also encompass single locality species that are close geographical neighbours. For example, Zone Sn2 approximates the geographical range of Pseudolaureola new species 1 (Figure 4.14) and includes the single locality species Acanthodillo species 3 (Figure 4.16)and Pseudodiploexochus species 3 (Figure 4,19) and Buddelundia species 5 (Figure 4.14.).

8.2.2. ENDEMISM WITHIN THE MODEL

The Main Line (Figure 8.1A) creates quite a remarkable division of taxa. Forty-one taxa are endemic to either the Northern or Southern Subregions. This represents 68% of the sixty indigenous mainland taxa. Twenty-one taxa are found only in the northern zone (N), twenty only in the southern zone (S) and nineteen taxa are found in both zones. Most of the Buddelundia are found in only in the north while all Pseudolaureola are found in the south. The other Armadillid genera Acanthodillo, Spherillo and Cubaris have endemics in both subregions.

Among the taxa found in both subregions there are some found mainly in one subregion but with outliers in the other. Styloniscus species 7 (Figure 4.6) is found mostly in the Southern Subregion but has an outlying population in the Northern Subregion. Laevophiloscia species 2 (Figure 4.2) is similar but has more outliers in the north. Platyarthridae species 3 (Figure 4.10), Hanoniscus new species (Figure 4.27) and Buddelundia nigripes (Figure 4.26) occur in both the Northern and Southern Subregions but do so because their distribution extends northward up the coast. Acanthodillo species 2 (Figure 4.9) occurs predominantly in the Northern Subregion but has a single outlier in the south. In contrast, Acanthodillo species 5 (Figure 4.9) occurs widely throughout the southern subregion but has a single outlier in the north.

Second order delineations recognise an obvious boundary formed by the Darling Scarp (the Darling Scarp Line) that splits the northern part of the jarrah forest from the rest of the Swan Coastal Plain. Another boundary (the "Nicholls Line") is recognised, which splits the main part of the wetter southern forest from the remaining forests. Each of the four macrozones created by second order delineations have a similar number of endemics with the highest endemism, nine taxa being found in the largest zone (Sn). The far-south macrozone (Ss) and the northeast macrozone (Ne) both have eight endemics while the northern coastal macrozone (Nw) has slightly less with six endemics. The coastal macrozone Nw does however contain some outliers of coastal taxa that are found in macrozone Sn. Over half (52%) of the indigenous mainland taxa described are endemic to one of the four macrozones.

Third order delineations are made largely in the largest macrozone Sn. Endemic taxa in macrozone Sn have much shorter ranges than those found elsewhere. Following the third order delineations, the largest zone created, zone Sn1, has no endemic taxa at all. Endemism is represented by four smaller zones. Of these, Zone Sn2 is the most significant with four endemic taxa. The other zones (Sn3, 4 & 5) have one or two endemics.

Even at this scale, a third of the regional taxa are found only within one zone. In addition, there are two very short-range endemics found on the Darling Scarp at the western edge of zone Ne1. This pocket could have been included as a separate zone, but the taxa distributions occur at too small a scale to be adequately represented in Figure 8.1C. However, it should be noted that short-range endemics are certainly a feature of Zone Ne1, if not all zones. It may be that a long history of sampling in this part of the region has highlighted these species, or possibly that endemics in Zone Ne1 are related to landscape characteristics and less influenced by exogenous disturbance than taxa in other forested zones.

The biogeographical model described in Chapter 6 included the eastern Zone 7 (Kojonup Woodlands) characterised by the presence of a few locally distributed Eastern Pattern species and by the absence of many regionally distributed and forest species. This zone was not included in the revised model. Much of the landscape in this part of the region has been cleared of its natural vegetation and so the zone has too few sampling sites to assess adequately the affinities of the taxa. It was shown in Chapter 6 to be data deficient. While there is certainly a distinct terrestrial isopod fauna in this part of the region, there is not enough distributional information to accurately determine a biogeographical boundary at this stage. However, the species found in this area are either found in the Northern Subregion (e.g. Hanoniscus tuberculatus) or are closely related to species found there (e.g. Buddelundia albomaculata). Zone 7, as defined in Chapter 6, was included as part of Zones S, Sn and Sn1. Consequently, the eastern boundary of Zone Sn1 shown in Figure 8.1C is shown as a dotted line.

8.2.3. LANDSCAPE DIFFERENTIATION REVISITED

Chapter 5 introduced the concepts of landscape and geographical differentiation. Landscape differentiation (beta diversity) is a measure of species turnover among the different communities within a landscape or between habitats (Whittaker, 1977). This was examined using preliminary landscape units in Figure 5.6. Geographic differentiation (delta diversity) is the turnover of species along climatic gradients or between geographic areas (Whittaker, 1977), and has not yet been evaluated. Since Figure 8.1C has presented meaningful and refined landscape units, it is now appropriate to re-examine landscape diversity and to assess geographical differentiation by examining the degree of species turnover among the zones.

Figure 8.2 shows landscape differentiation, expressed by a two-dimensional MDS plot of the species composition of the localities (with two or more taxa), coded according to the zone in which they occurred. In order to create a clearer interpretation, the coastal Zones Nw1, Nw2 and Nw3 have been combined and plotted as the macrozone Nw. The ordination was based on a presence/absence Bray-Curtis similarity matrix. Localities in the northern Zones Nw and Ne are in blue, localities in the central Zones Sn1, Sn2 and Sn3 are in red and localities in the southern Zones Ss1, Sn4 and Sn5 are shown in yellow.

Figure 8.2 shows clearly the difference between the northern and southern macrozones. The northern localities are well differentiated from those in the south and are also more spread out. This both highlights the importance of the Main Line and reinforces the concept of greater landscape differentiation in the north of the region shown in Chapter 5. The northern coastal zone Nw (blue triangles) also shows greater landscape differentiation than the northern forest zone Ne (blue circles). Given that a major faunal break was hypothesised earlier, it is not surprising that localities in the far-south of the region (yellow) are well separated from those in the north. Zone Ss (yellow circles) shows relatively low landscape diversity but has some localities with similar species composition to the larger forest zone Sn1 (red squares). Like the large forest macrozone Ne, zone Sn1 also has high landscape differentiation. The two zones are either side of the Main Line and have quite different taxa. The small, high endemism Zone Sn3, representing a wetter part of the jarrah forest, has the lowest landscape differentiation with the all four contributing localities grouped very closely together. Its affinity to the southern zones is also well illustrated by Figure 8.2.

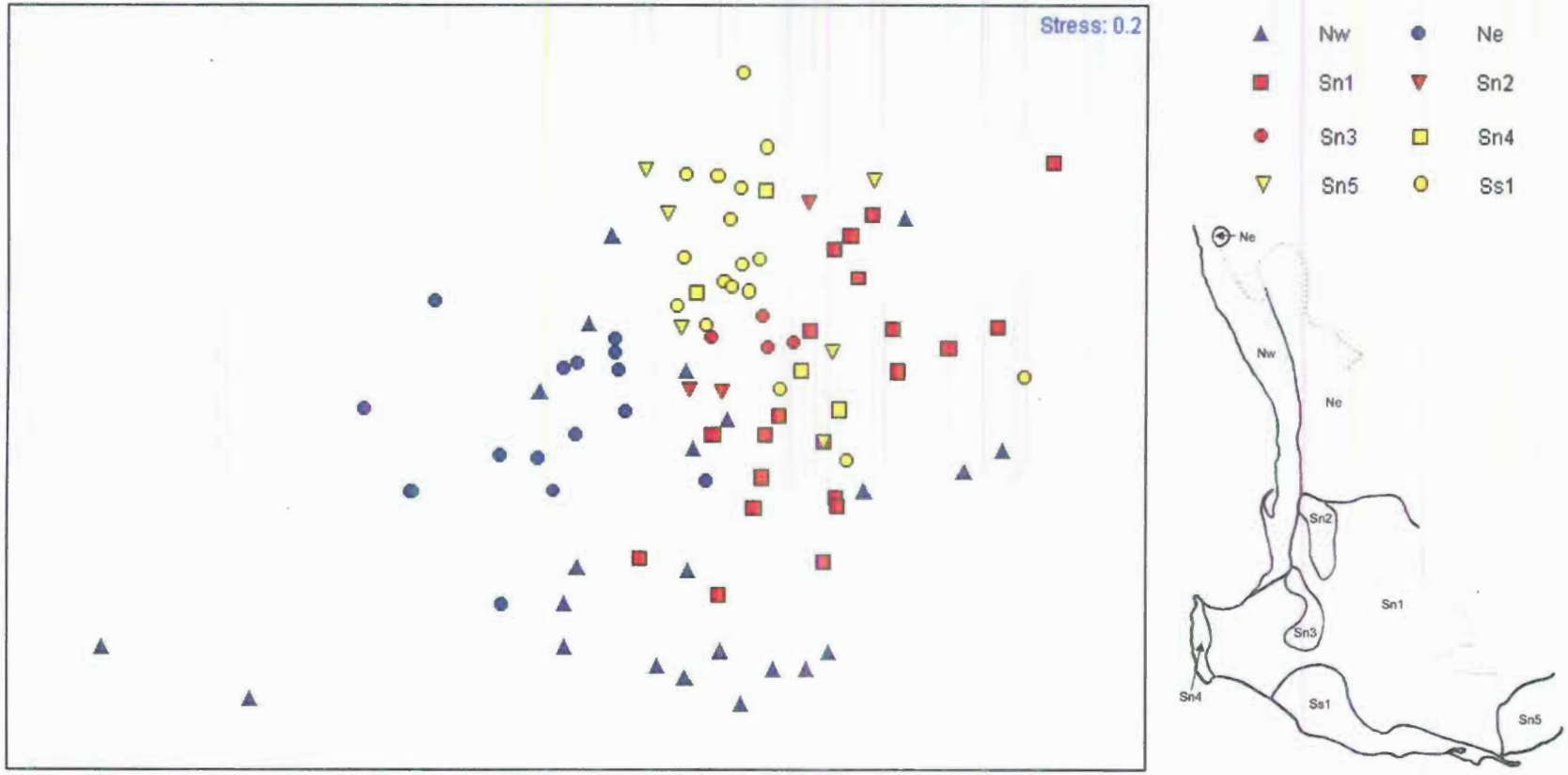


Figure 8.2. Landscape differentiation expressed by a two-dimensional MDS plot of the species composition of the localities with two or more taxa present. Localities are coded according to the zone or macrozone in which they occurred (inset). Localities found to the north of the Main Line are shown in blue, those to the south are in red and the far south are in yellow.

8.2.4. GEOGRAPHICAL DIFFERENTIATION

Figure 8.3 shows geographical differentiation expressed by a two-dimensional MDS plot of the species composition of each of the zones. The colour scheme and pattern of shapes is the same as that used in Figure 8.2. A presence/absence Bray Curtis similarity matrix was used to generate the plot. Whereas in Figure 8.2 the coastal zones Nw1, Nw2 and NW3 were grouped and expressed as a macrozone, in this figure, the northern sandplain of the Swan Coastal Plain Bioregion, represented by Zone Nw1, is separated from the more coastal Zones Nw2 and Nw3.

The geographical differentiation between the northern and southern half of the region, as delineated by the Main Line, is again starkly evident. Northern zones are discretely separated from the central and southern zones. The large, central forest Zone Sn1, is in the centre of the plot because it contains no endemics and contains only widely distributed taxa with some outliers from both the northern and southern zones. In terms of geographical differentiation, it appears to contain taxa more associated with the southern zones. The three zones comprising the Warren Bioregion are relatively closely grouped. Zone Sn4, representing the Cape to Cape region, appears closer to zones outside the Warren Bioregion probably because it contains some coastal species whose distributions extend northward and dissect the Main Line.

Zones Nw1 and Sn2 are the most geographically differentiated but for different reasons. Zone Nw1 is a large zone of low diversity containing only widely distributed taxa and some outliers from the adjacent northern zones. Zone Sn2 is also a zone of low richness but with important endemic taxa related to taxa found in the wetter south. Figure 8.2 shows not only its differentiation from other zones but also its important contribution to regional diversity. Zone Sn3 is also important in this respect but is closer to the three southern zones because it contains outlying southern taxa and has less endemics. Nevertheless, its contribution to regional diversity is important.

To some extent, the differentiation of the zones shown in Figure 8.3 serves to validate the model constructed earlier. Zones that had previously been delineated by an intuitive analysis, have now been demonstrated statistically. Although this analysis was undertaken using the same data as previous chapters, the fact that similar results were obtained suggests that the methods employed previously were adequate. While this is an "internal" verification of the model and not a true test of its validity, the degree to which the model represents the biogeography of the region can be assessed independently by examining its degree of concordance with other biogeographical interpretations of the region. This is the purpose of the next section.

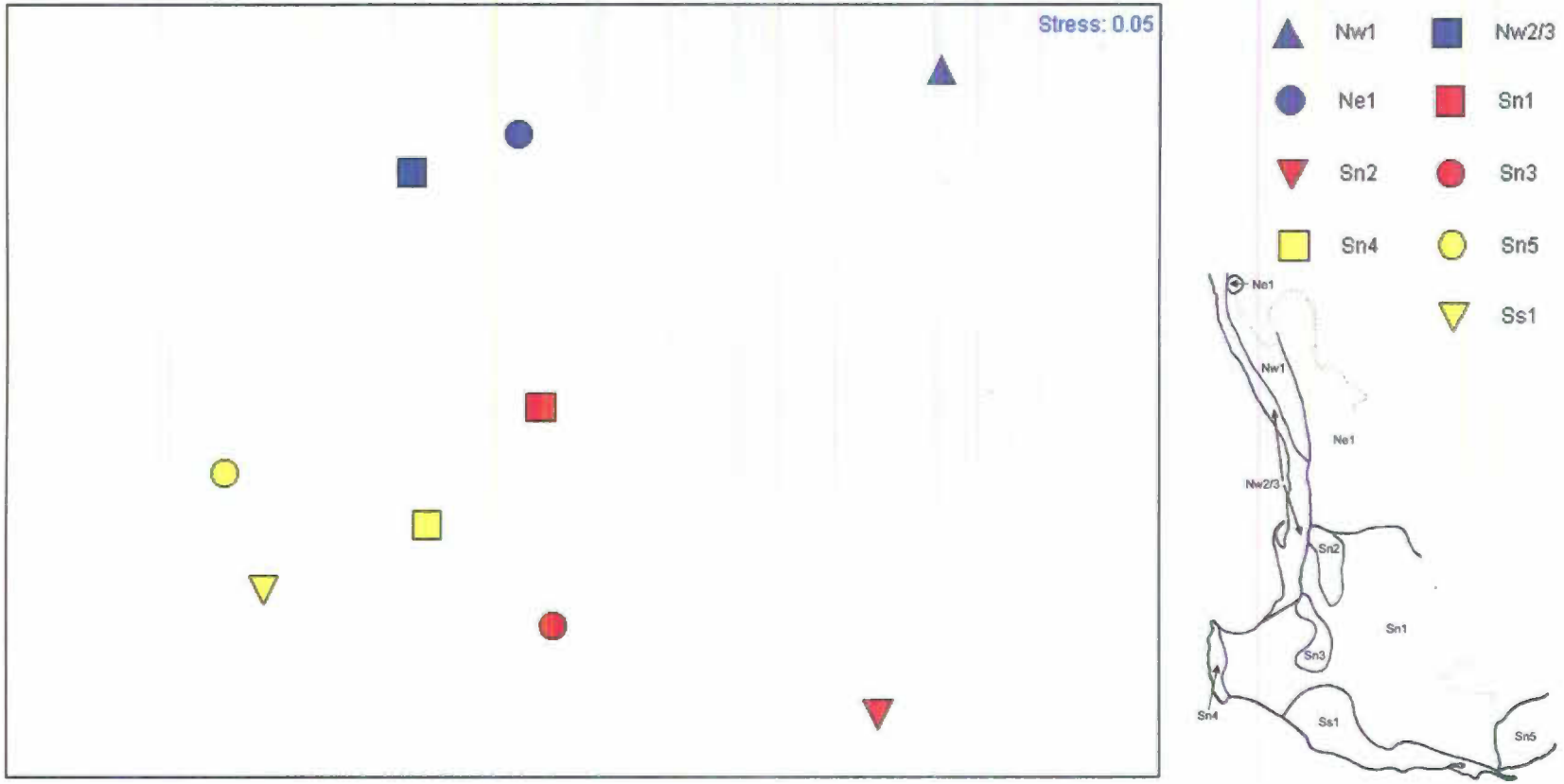


Figure 8.3. Geographical differentiation expressed by a two-dimensional MDS plot of the species composition of the zones or macrozones (inset). Zones north of the Main Line are shown in blue, zones to the south are in red and the far south are in yellow.

8.2.5. EVALUATION OF THE MODEL

There are very few biogeographical studies of invertebrates in southwestern Australia and none covering the region in the same systematic way as employed in this study. As a first step in examining the validity of the model, it is perhaps prudent to assess it in respect to the established bioregions since they are designed to reflect a number of floristic, faunistic, and climatic boundaries.

Figure 8.4A shows the model superimposed upon bioregions of Thackway and Cresswell (1995). The most striking feature of the comparison between the two schemes is that first order delineations of the Northern and Southern subregions do not concord with the currently recognised biogeographical boundaries that depict the IBRA bioregions. The Main Line transgresses both the Jarrah Forest and Swan Coastal Plain Bioregions. There appears to be some affinities of taxa with the Dale and Menzies botanical sub districts (see Figure 1.2) but the biogeographical boundary created by these two subdistricts is further south than the Main Line. Similar biogeographical affinities in forest insects were noted by Abbott (1995) but his study did not delineate a precise boundary. The Jarrah Forest Bioregion does not represent a biogeographical boundary in the distribution of the terrestrial isopod fauna. This is interesting given the observation made about the delineation and nomenclature of the Jarrah Forest Bioregion in Chapter 1, Section 1.5.4.

In contrast to first order delineations, second order delineations conform more closely to the biogeographical boundaries used to represent Bioregions. In the north of the region, the model makes a clear delineation concordant with the boundary of the Jarrah Forest and the Swan Coastal Plain Bioregion. However, the boundary between the Nw and Ne macrozones appears to be a little to the west of the IBRA boundary determined by Thackway and Cresswell (1995). The landforms of the Ridge Hill Shelf and the Pinjarra Plain, usually considered as part of the Swan Coastal Plain (Seddon, 1973), contain species more associated with the Jarrah Forest Bioregion than with the Swan Coastal Plain Bioregion. The Darling Scarp Line as also serves as a biogeographical boundary for ants (Rossbach and Majer, 1983), Crinea frogs (Paterson & James, 1973) and lizards (How & Dell, 1994). Rossbach and Majer (1983) showed patterns in ants species distribution in the north of the region similar to those presented here. Species were commonly absent from the Darling Scarp and present on the Swan Coastal Plain, or confined to particular belts (longitudinal zonation) of the coastal plain or the Darling Scarp. The high locality diversity of twenty-one taxa shown by the Fremantle locality (Locality 25) in Chapter 4 is explained by Figure 8.4B. The locality contains not only all the landforms of the Swan Coastal Plain as well as the Darling Scarp but also the environs of the Swan River and its estuary. The species rich zones of Ne1 and Nw2 overlap here and there is also some small-scale endemism associated with Darling Scarp. These features combine to create an area of high diversity.

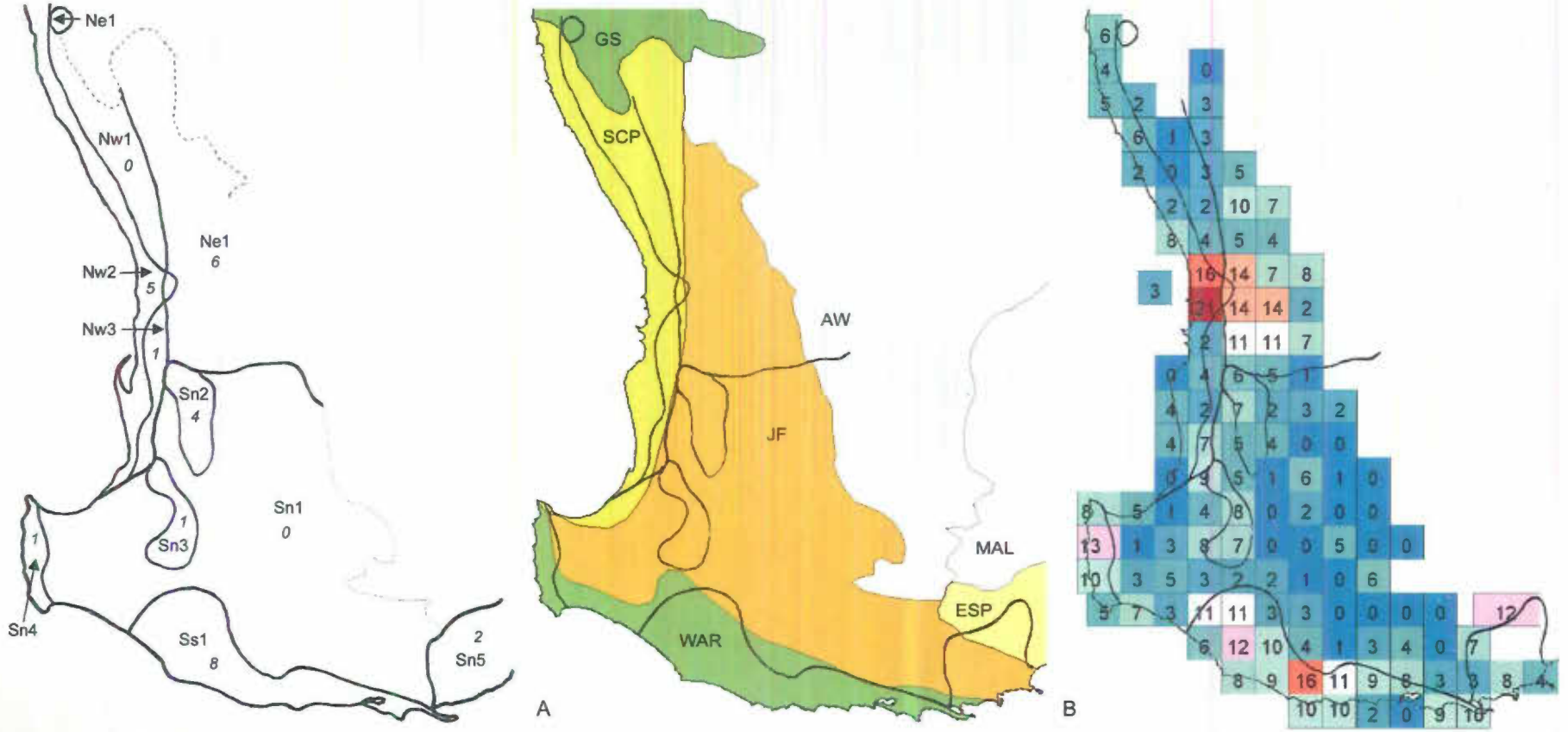


Figure 8.4. The zones determined in Figure 8.1C superimposed upon (A) the bioregions of Thackway and Cresswell (1995) and (B) the pattern of locality diversity determined in Chapter 5. The Bioregions of Jarrah Forest (JF), Swan Coastal Plain (SCP) and Warren (WAR) formed the study area. Also shown are the adjacent Geraldton Sandplain (GS), Avon Wheatbelt (AW), Mallee (MAL) and Esperance Plains (ESP) bioregions.

The Warren Bioregion is largely synonymous with the distribution of karri. The northern boundary of the Warren botanical subdistrict (sensu Beard, 1980) "is drawn where E. diversicolor ceases to be a significant component" (Hopper, Keighery & Wardell-Johnson, 1992, p 2). The subdistrict contains some 1628 vascular plants of which 99 are endemic and many more occurring just outside the region or having geographical outliers. It is an important centre of endemism for high rainfall taxa (Hopper, Keighery & Wardell-Johnson, 1992). The model provides further evidence of high endemism but presents a slightly different biogeographical pattern. There is a general concordance with the boundaries of the Warren Bioregion and Zone Ss in the central part of the bioregion. This is not surprising since the karri tree is both an important microhabitat component for terrestrial isopods (Section 4 5.1) and a defining component of the bioregion However, the Zone Ss, defined by the Nicholls Line to include the eight endemic taxa, represents a contraction of the biogeographical boundaries used to delineate the Warren Bioregion. Other than outliers of P. wilsmorei and Buddelundia species 6, there is little to connect it with the western part of the Warren Bioregion (Zone Sn4) However, these zones are faunistically similar and the boundaries of the Warren Bioregion hold true for other taxa Relationships between these zones are known from the Geocrinia (Anura: Myobatrachidae) complex (Wardell-Johnson & Roberts, 1996), the burrowing freshwater crayfish genus Engaewa (Decapoda: Parastacidae) and Cherax crassimanus (Decapoda Parastacidae) (Horwitz & Adams, 2000).

The smaller zone, Ss1, defined here is, however, consistent with, or encompasses the distribution of, other moisture-dependent taxa such as the frog Geocrinia rosea. (Myobatrachidae) (Wardell-Johnson & Roberts 1996) and, to a large extent, the ancient freshwater fish Lepidogalaxias salamandroides (Lepidogalaxiidae) (Christensen, 1982) among others. L. salamandroides exists in ephemeral peaty sedge lands, often darkly stained (Morgan et al , 1996), and has adapted to cope, to some degree, with seasonal aridity (Hopper, et al , 1996). Eight of the nine species of native fishes occurring in the karri forest streams, encompassed by Zone Ss, are endemic to the region (Christensen, 1982).

High local diversity, of sixteen and eleven taxa rerspectively, was evident in the high rainfall localities of Deep River (Locality 107) and Mount Frankland (Locality 108) respectively. This part of the Warren Bioregion is known for short-scale endemism amongst aquatic fauna such as decapods, aquatic isopods, aquatic mites and worms (Horwitz, 1997). Despite the limited taxonomic resolution of important genera that have been demonstrated to be diverse in wet areas elsewhere (e.g. Styloniscidae, Green, 1971), there is still evidence of short scale endemism in this area Horwitz (1997) suggested that locally endemic fauna are likely to occur inter alia, close to the coast, in areas of high rainfall with little seasonal drought and where organic material accumulates These characteristics apply equally well to terrestrial isopods

The richness of Zone Ss covers all the families examined here. What is notable is that there is a much higher richness of Armadillidae than has been recorded for the wet forest areas of Tasmania detailed by Green (1974). While there are undoubtedly more discoveries to be made in both areas, the diversity of Armadillidae in zone Ss is more than the six species described from the whole of Tasmania given by Green (1974). This part of the region is noted for a conspicuous Gondwanan heritage Main (1991) describes a species of mygalomorph (Moggridgea tingle) from the Walpole Nornalup area The species is from a "classic Gondwanan family" (Main, 1991, p.383). Main noted that all nests of the species were in damp and shaded areas and some populations had apparently been lost to recent recurrent fires.

A recently discovered species of frog, the monotypic Spicospina flammocaerulea, occurs in a few peaty swamp areas in Mount Frankland locality (Locality 108). Its persistence depends upon peaty swamps with organic rich soils where fresh water seepage maintains moisture conditions into the drier period (Roberts et. al, 1996). In other areas of Warren Bioregion, restricted moisture-dependent endemics also occur. Coastal springs of the far south of the Warren Bioregion provide habitat for the restricted endemic freshwater snail Westrapyrgus westralis (Hydrobiidae) (Ponder, Clark & Miller, 1999). The only other representative of the family Hydrobiidae in Western Australia, W. slacksmithae, is found in the northern subregion in the Avon and Moore Rivers. This highlights once again the north-south disjunction in the distribution of moisture-dependent invertebrates. The monotypic Austroassiminea (Assimineidae), a rare and endangered prosobranch snail, is even more restricted than Westrapyrgus. It occurs in seepage and splash zones of fresh water streams near the coast in the Leeuwin locality (Locality 85) (Solem et al., 1982).

There is some concordance of Zone Ss with the former distributions of some rare and threatened birds of south–western Australia. While their distributions were perhaps wider than now, parts of the wet southern Zone Ss might perhaps be an important refuge, particularly from fire A review of the threatened vertebrates of the southwest forests by Judd (1994) included 28 formally listed species and suggested that the status of the avifauna was the least known of all vertebrate taxa Of the eight bird species categorised as "insufficiently known", four were wetland birds and four were forest birds Two subspecies of birds, the south-west rufous bristlebird (Dasyornis broadbenti litoralis) previously found in dense coastal scrub in Zone Sn4 and the far south of Zone Ss1, and Lewin's water rail (Rallus pectoralis clelandi), which was found in rushes at the margins of swamps, originally endemic to Zone Ss, are considered extinct Three other endangered birds; western bristle bird (Dasyornis (brachypterus) longirostris), noisy scrub bird (Atrichornis clamosus) and the western ground parrot (Pezoporus wallicus flaviventris), previously found patchily throughout forested areas in Zone Ss and surrounding zones, have disappeared from zone Ss and are now confined to Zone Sn5 or to the east of it

Altered fire regimes are suggested as a cause for the decline of all species (Storr, 1991, Garnett, 1992) The fact that these species, and other forest vertebrates, are extant is thought to be a result of the "fortuitous exclusion of fire" (Calver & Dell, 1998, p. 316).

Although there are taxa that are distributed throughout Zone Ss1, there is also an indication that there are distinct populations present. This is best demonstrated by Pseudolaureola and in the distribution of P. wilsmorei in particular. It is likely that greater taxonomic resolution will demonstrate many pockets of short scale endemics and perhaps also the relictual nature of the taxa found there. The central part of the Warren Bioregion contains four endemic large forest eucalypts (Wardell-Johnson and Coates, 1996), namely Eucalyptus brevistylis (Rate's tingle), E. jacksonii (red tingle), E. guilfoylei (yellow tingle) and E. ficifolia (red-flowering gum). These species indicate important patterns of genetic differentiation between populations suggesting that they have been periodically isolated and separated over evolutionary time. E. ficifolia reflects the importance of moisture as it is found only in humus podzols, usually in the interface between inter-dune swamps and areas of granitic terrain. Wardell-Johnson and Coates (1996) suggest that these four species of locally endemic forest eucalypts are indicators of small-scale high rainfall, non-mobile relictual biota.

While Zone Ss1 shows some concordance with the Warren Bioregion and contains many endemic taxa, there are parts of the Jarrah Forest Bioregion that also contain significant endemics related to those found further south. Beyond the high rainfall, less seasonally dry southern karri forests, the persistence of moisture-dependent taxa is more obviously localised. Zone Sn5 is characterised by the presence of both the Stirling and Porongurup Ranges. The refugial role of upland areas, such as the Stirling Range (Supplementary Locality 201) and Mount Lesueur (Supplementary Locality 202), has been noted for plants (Hopkins et. al, 1983, Marchant, 1973), and the Stirling Range (Locality 201) and Porongurups (Locality 104) for relict mygalomorph spiders (Main, 1999). As seen in Chapters 4 and 7, surface organic matter and their capacity to provide moist microhabitats are critical to the short-range endemics. This is clearly illustrated by Pseudolaureola in Zones Sn2 and Sn3. Endemics taxa have yet to be demonstrated for much of the Jarrah Forest Bioregion (Zone Sn1). The fact that the jarrah forest is a very heavily modified and intensely utilised ecosystem (Heberle, 1996, Calver & Dell, 1998), and that such a large zone can contain no endemic taxa, where endemics in adjacent zones are related to surface organic matter, is probably not coincidental.

8.3. ORIGIN OF THE FAUNA

The evolution of the terrestrial isopod diversity in southwestern Australia depends largely upon two things: the age of the groups as a whole and upon the climatic and tectonic characteristics of the region throughout their evolution. There is no real clear indication of

the age of the Oniscidea. Jass and Klausmeier (2000) point to the fact that fossil terrestrial isopods do not appear until the Eocene. However, by then, terrestrial isopods were already recognisable as modern genera and the fossil record of the terrestrial isopods generally postdates the angiosperms (Little, 1983 cited in Pearce, 1989). The distribution of Styloniscus (Vandel, 1955), the relationship of Pseudodiploexochus with Africa, (Taiti & Ferrara, 1979), Madagascar (Taiti & Ferrara, 1983), Brazil (Lemos de Castro, 1972) and Lord Howe Island (Lewis, 1998), and Pseudolaureola (although the taxonomy of the genus needs extensive revision) with Madagascar, New Caledonia and St. Helena Island (Dalens, 1998) all suggest Gondwanan affinities. Taiti, Paoli and Ferrara (1998) indicated a Gondwanan origin for the family Armadillidae. Vandel (1965, 1973, cited in Pearce 1989) suggested that terrestrial isopods originated in the Carboniferous. This view is supported by Pearce (1989) who hypothesised that organic-rich (mull) soils capable of supporting substantial macro-decomposer communities, including isopods, could have existed prior to development of the fossil mull soils analogous to the appearance of the angiosperms. The litter of pteridophytes, that would have constituted much of the surface organic matter prior to the Tertiary, is also palatable to modern terrestrial isopods (Pearce, 1989) and is certainly utilised in remnant Australian rainforests (Ashton, 1975). What seems certain is that terrestrial isopods were well established by the end of the Mesozoic. What is debatable is whether, what appear to be Gondwanan distributions, are the result of dispersal following the break up of Gondwana or the presence of ancestral Gondwanan taxa. There are clear southern hemisphere groups, Indo Pacific groups and sub-Antarctic groups. The family Armadillidae is thought to have arisen somewhere in south-east Asia (Schmidt, 2002) although no time is yet determinable.

Perhaps the most notable historical biogeographic features of the south-western Australia are that it has remained unglaciated since the Permian and without major tectonic events (Hopper et al., 1996). It is consequently topographically subdued (Hopkins, et al. 1983; Hopper et al., 1996) with nutrient poor soils (Mulcahy, 1973). Therefore, the evolution of the region's Oniscidea has been unaffected by the extermination of terrestrial isopods from many areas during Quaternary glacial events, as has been the case in the northern hemisphere (e.g. Jass & Klausmeier, 2000). South-western Australia has therefore the potential to have retained many of its Gondwanan links among its terrestrial isopod fauna. Rather than the direct effects of the great ices sheets of the Quaternary, it is the period pulses of their associated climate change that have been the great speciation mechanism upon the region's Oniscidea An overview of the critical climatic events and other likely impacts upon the Oniscidea, drawn from the most pertinent literature, now follows

If Vandel's (1973a, 1973b) interpretation of the genus Australoniscus is correct, then south western Australia has retained some of the oldest Gondwanan links amongst the terrestrial isopods. The distribution of Australoniscus is also remarkable, represented by

two species being found only at the Porongurup Range in Western Australia (Vandel, 1973a) and in Nepal (Vandel, 1973b). The splitting of Gondwana first occurred about 110 ma BP when the Indian continental plate separated from the Leeuwin-Naturaliste ridge. The granite Porongurup Range (~1,1510 myo) is a geological relic of the birth of Gondwana (Hopper, et al 1996). The break-up of Gondwana proceeded through the Cretaceous with the breaking away of Africa (~80 ma BP), at which time the southwest of Western Australia remained connected to the rest of Antarctica through eastern Australia. Finally, some 65 million years ago, the Australian continent separated from Antarctica as the last land ridge between Tasmania and Antarctica was covered by marine waters. At this time, despite being close to the South Pole, much of southern Australia, including south-western Australia, was covered by rainforest (Hopper,et al., 1996). In evolutionary terms, it seems appropriate for analysis of the origin of the regional fauna to commence at the end of the Cretaceous and include the Cainozoic events of the Tertiary and Quaternary.

8.3.1. TERTIARY EVENTS

The greater part of the Yilgarn Block remained above sea level, avoiding the extensive marine transgressions that periodically covered much of inland Australia during the Eocene. Extensive rainforest coverage would have allowed for wide dispersal of diverse terrestrial isopods communities throughout the greater part of the Tertiary. Potentially, highly productive forests combined with moist conditions would allow for the development of species-rich decomposer communities. Marginal areas of rainforest, allied with the development of the sclerophyllous genera of Myrtaceae and Proteaceae so common today, would allow for gradual development of new species capable of utilising seasonally or permanently drier ecotypes with surface organic matter of a different nutritional quality.

Probably the single most significant event in the regional evolution of the terrestrial isopods was the late tertiary extinction of rainforests in Western Australia and the onset of aridity. This process would have first isolated south-western Western Australia Oniscidea from the rest of the continent and would undoubtedly have resulted in the extinction of much of the rainforest Oniscidea in south-western Australia. The fact that there are many fewer genera of terrestrial isopods in south-western Australia forests than in Eastern Australia[15] reinforces this notion. Nevertheless, significant components would have persisted in both moist cryptic microhabitats throughout the region and in wetter areas where elements of the rainforest plant communities persisted.

The exact timing of these events is unclear, but Archer (1996) argues that the dramatic onset of late Tertiary aridity would not have occurred before the Middle to Late Miocene.

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[15] Although this may change with greater taxonomic resolution of Australia's terrestrial isopods

Pollen cores suggest that remnant pockets of rainforests occurred 200 km north of Perth (at the northern limit of the study area) during the Pliocene between 3.6 and 2.5 Ma BP (Hassell & Dodson, 2003). The faunal relicts of these remnants persist at various places throughout what is currently a Transitional Rainfall Zone (sensu Hopper, 1979) at the micro scale in response to topography, soil texture and moisture retention potential, vegetation cover, particularly shading by canopy and litter cover (Main, 1996b).

At this time, the wet forests of the region probably contracted to the very far south west corner and south coast. Such remnants were probably too small to retain populations of refugial vertebrates of the Miocene rainforests (Archer, 1996) but not plants and invertebrates. Rainforests have not persisted in the southwest of Western Australia but rainforest faunal elements have.

Bowman (2003) argues that fire became much more prevalent throughout the late Tertiary due to a regular ignition source, namely lightning. Bowman (2003) relates the emergence of the giant eucalypts such as E. diversicolor to the onset of aridity and the increasing frequency of fires in the landscape. He suggests that the fact that wetter areas of south-western Australia have climates suitable for rainforest (e g. >1100 mm yr^{-1} annual rainfall and a seasonal drought <3 months) but do not support rainforests is because no continuously regenerating and fire intolerant rainforests were able to compete with E. diversicolor.

The process of the replacement of true rainforest with wet sclerophyll would have been a major speciation process for the region's Oniscidea. In eastern Australia, rainforest fragments, isolated pockets of the southern beech (Nothofagus cunninghamii) and related Gondwanan plants still occur (Howard & Ashton, 1973). This is not the case in the southwest of Western Australia, where Gondwanan plants are more associated with wetlands and damplands in the southern part of the region. Examples are the monotypic Reedia and a few sedges in the Gondwanan families Anarthriaceae and Ecdeiocoleaceae (Hopper et al., 1992). It is likely that Gondwanan elements of the terrestrial isopods, other than those distributed in the most cryptic of microhabitats, and certainly those found in forest leaf litter, must have developed a means of consuming the sclerophyllous leaf, particularly eucalypt leaves. While all Mediterranean-type shrublands are generally described as sclerophyllous, Beard, Chapman and Gioia (2000) suggested that sclerophylly is more prominent in Australia. Its predominance is demonstrated by the large numbers of species of sclerophyll shrubs and their high endemism compared with other floristically diverse Mediterranean-type regions (Beard et al., 2000).

Events at the end of the Tertiary probably left the region with a few rainforest relics existing in moist areas of the far south, throughout the region in upland areas such as the Porongurup and Stirling Ranges and cryptic moist microhabitats throughout the

landscape. There would also be some taxa adapted to drier niches that would have expanded their distribution quite significantly at this time.

8.3.2. QUATERNARY EVENTS

Cranston and Naumann (1991) suggested that climatic and environmental fluctuations of the Quaternary have been of great significance in promoting speciation among Australian insects. The principle speciation mechanism, they predicted, would have been the periodic isolation of moisture-dependent taxa in refugial pockets of wet forest surrounded by inhospitable drier vegetation. Similarly, populations of taxa adapted to drier woodland would be dissected by both temporary expansions of wet forests and areas of aridity expanding outward from the centre of the continent. The same processes can be considered applicable to terrestrial isopods, probably more so considering their limited dispersal capability and less diverse morphology.

The pattern of speciation of the region's Oniscidea therefore needs to be evaluated in the light of Quaternary environments. During the Quaternary, prior to arrivals of humans on the continent, much of Australia experienced cycles of aridity related to glacial and interglacial climatic intervals (Singh, Kershaw & Clark, 1981). Marked changes in vegetation communities, determined by palynology, have shown cool dry climates during glacial periods and warmer, wetter phases during interglacials. The timing of these is probably of little importance to the arguments and discussion presented here; suffice to say that cool arid periods and warmer periods occurred throughout the later part of the Quaternary. What is more important is that warmer cycles are associated with the increasing development of Casuarina and then Eucalyptus vegetation.

There have been various hypotheses put forward for climatic and/or eustatic events for south-western Australia in the Holocene (e.g. Churchill, 1959, 1968; Kendrick, 1977, 1971; Wyroll, 1979; Kendrick, Wyroll & Szabo, 1991; Backhouse, 1993). Semeniuk (1995) suggested that there is not conclusive evidence to determine whether there are "unequivocal cycles or modulated pulses of change". There is little consensus other than there have been one or more phases of aridity during the Holocene (Semeniuk, 1995). The degree of aridity and the timing of events are unclear. Semeniuk's review (1995) suggested that all studies conferred a period of aridity during the mid Holocene. Churchill (1968), based on the relative ratios of E. diversicolor and E. calophylla pollen, suggested a cycling of wet and dry conditions during the Holocene resulting in increasingly wet conditions from c. 2.5 ka BP until the present day. Kendrick (1977), from interpretations of changes in communities of estuarine molluscs, suggested an arid period took place between 6.6 ka and 4.5 ka BP. Newsome and Pickett (1993) on the other hand considered the ratios of eucalypt pollen inputs to have remained fairly constant throughout the past ca. 4 5 ka and that fluctuations in the ratios of eucalypt species need

not reflect changes in rainfall at all, and may be due to non-climatic factors. Evidence for the northern Swan Coastal Plain (Newsome & Pickett, 1993) covers the last c. 9000 years. Most substantial organic deposits in south-western Australia so far investigated date back this far (e. g. Newsome & Pickett, 1993; Churchill, 1968; Ryder, 2000) while others commence at around 6.5 ka BP (Horwitz, Pemberton & Ryder, 1999) or around 4.8 ka BP (Dodson & Lu, 2000). The ages of these profiles may be suggestive of the arid phases predating their establishment.

In the period 5 – 10 ka BP., it has been postulated that the climate of southern Australia was much wetter than today (see references in Hopkins et al., 1983). This view has been derived from studies in eastern Australia where it appears that the critical climatic feature over much of the continent has been variation in rainfall. For example, Kershaw and Nanson (1993) suggested that the last global glacial-interglacial period incorporated the range of conditions experienced cyclically during a large part of the Quaternary. The driest conditions were experienced within the transition between the last glacial and the Holocene about 15-11 ka BP and a wet phase about 35-50 ka BP (Kershaw & Nanson, 1993). This concurs somewhat with conditions predicted to have occurred in the south west of Western Australia in that during the late Quaternary there was extensive aridity during the last glacial period (Wyroll, 1979; Semeniuk, 1995).

The contraction of the humid, or possibly sub-humid, zone to the far south western corner and south coast (sensu Semeniuk, 1995) before and during the Holocene would have profound repercussions for the Oniscidea. The degree to which the arid zone encroached upon what we now call the humid south west is also debatable. Glassford and Killigrew (1976) argue for a westward extension of the < 200 mm isohyet suggesting that Perth basin yellow sand is the result of previous localised desert conditions, a view supported by Newsome (2000). The arid zone has reached the coast a number of times, they suggest, the earliest being during the Pliocene and again in the Quaternary. With a comprehensive cladistic analysis, the terrestrial isopods would be an excellent group to test such hypotheses. They contain many species, are particularly rich in a few genera, and have species that are on both ends of the moisture dependency spectrum.

Quaternary eustatic changes in sea level have also been proposed. Freshwater peat deposits from the Swan River estuary were used by Churchill (1959) to demonstrate that sea levels have been rising since 14 ka BP. About 7000 ka BP, Rottnest Island was cut off from the mainland when an old dune topography between Perth and Rottnest Island became inundated. There is little evidence to suggest that sea levels have been considerably higher than at present but there is evidence that in the longer term (Plio-Pleistocene) sea levels have been periodically similar to those of today. It also appears that vegetation communities have been relatively stable since then (Newsome & Pickett, 1993; Hassell and Dodson, 2003). There is some evidence to support the existence of

tuart woodland or Eucalyptus-Casuarina woodland on Rottnest Island (Backhouse, 1993) and certainly, the terrestrial isopod communities on Rottnest Island resemble those of the Swan Coastal Plain, although they are not as diverse.

There is little doubt that early in the Holocene, and probably at some point later, conditions were much drier than at present. There is also evidence to suggest that at some point in the Holocene it was much wetter than it is today. The outlying distributions of the principal forest trees for example suggest that the high rainfall zone extended much further north and west than at present (Churchill, 1968; Hopkins et al., 1983), and there is evidence that in the wettest parts of the region small scale endemics have recently contracted in range (Solem, et al., 1982).

8.4. THE IMPORTANCE OF SURFACE ORGANIC MATTER

Whether fire has been central to the evolution of the Western Australian flora is debateable (Hopper, 2003). In the case of terrestrial isopods fire must be considered critical as it removes much of the dead organic matter within the landscape. It is likely that the accumulation of substantial organic deposits over the greater part of the Holocene has buffered sensitive taxa from both large and seasonal, short- and long-term cycles of aridity. The degree to which fire will remove organic matter will depend upon a number of climatic factors, topography, the ignition source(s) and the nature of surface organic matter (fuel). At a landscape level, organic-rich wetlands or wetland systems support important suites of invertebrate and vertebrate animals, and vascular and non-vascular plants. The conservation of this biota depends, to some extent, upon local hydrology but more importantly upon the physico-chemical characteristics regulated by the presence and condition of organic matter (Horwitz et al., 2003). The nature of the organic matter can regulate the physico-chemical properties of water. Water quality associated with such wetland soils has a tendency towards stained, slightly acidic, stratified, dystrophic water with bottom layers depleted in oxygen. Relictual taxa are often associated with such processes and therefore changes in the nature of surface organic matter, particularly wetlands soils, can jeopardise the persistence of such taxa (Horwitz et al., 2003).

The very presence of long-term accumulation of organic matter indicates that the types of fires with the capacity to remove such deposits have been absent from these parts of the landscape. This leads to two inevitable conclusions. Firstly, there are areas in the landscape that organic matter accumulates faster than it breaks down, and, secondly, with a few exceptions (e.g. Churchill, 1986), that some organic deposits have not been consumed by the fire regime of that period of time. In organic-rich soils, the spatial variability of fires is governed by the bulk density, moisture content and depth (Miyanishi & Johnson, 2002). Therefore, the persistence of moisture-dependent relictual biota is

related to the accumulation of organic matter and to the intimate relationship with moisture.

There is evidence that the process of organic matter accumulation has also occurred prior to the Quaternary. Salama et al. (1993) described relict drainage channels from the semi-arid parts of the Southwest Botanical Province. Patterns of sedimentation within these channels indicated alternating periods of erosion, deposition, fluviation and sedimentation. The relict channels contained peat, associated with black carbonaceous sediments and fragments of tree branches, which palynological techniques suggests date from the Pliocene to Miocene. Such deposits must have persisted despite the vagaries of wetting and drying and changing fires regimes. Main (1996b) linked the environmental history of such areas to the present day heterogeneous distribution of relictual mygalomorph spiders.

In the south-western Australia, rainforest elements as above have co-existed with fire and very marked climate changes since the Pleistocene (Hassell & Dodson, 2003). So how has this been possible? In short, edaphic factors, the accumulation of surface organic matter and the retention of wet places in a drying landscape have buffered moisture sensitive taxa from the vagaries of climate and fire. Of fundamental importance to the persistence and evolution of surface-active terrestrial isopods has been the distribution and properties of surface organic matter.

In rainforest environments such as those found in patches in eastern Australia and some temperate ecosystems, broad-scale litter decomposition is driven by invertebrate communities of which terrestrial isopods are a conspicuous component (see introduction to Chapter 6). Western Australia's old soils, sclerophyllous vegetation and long association with fire has changed the nature of decomposition. Howard (1973) found that in the litter of Nothofagus cunninghamii forests of Victoria and Tasmania, isopods comprised a large part of the biomass of the invertebrates decomposer community. Ashton (1975) also highlighted the prevalence of isopods in the litter of Eucalyptus regnans forest with a ferny understorey. The densities of crustaceans (isopods Notoniscus and Schismadillo[16] and the amphipod Talitrus kershawi) reached up to 900 m^{-1}. This is not the case in the forests of south-western Australia. Isopods constitute only a minor numerical component of most studies (Springett, 1976, 1979; Abbott 1984, Postle, 1985) and talitrid amphipods are rarely encountered in forests, being found only in any large numbers in the wettest of litter (perc. obs.). Clearly, relictual invertebrate and plants occur at a much smaller scale in south-western Australia than in other areas of the continent. Such scales have not only driven the speciation of such organisms but also

[16] This species was later described as Schismadillo ashtoni Vandel 1973 and is the southern most occurrence of the genus Other species occur in Queensland, Northern Territory, PNG and New Caledonia

inevitably left many prone to extinction. The distributional scale at which populations of moisture-dependent isopods (and other moisture-dependent taxa) have occurred in the past would have been governed by a number of interrelating factors. Changes in litter type, as the prevalence of fire intolerant plant communities were reduced, changes in climate and fire regimes would all have been important. All these factors must be considered as mechanisms for speciation in the terrestrial isopods of the region. In a landscape of subdued topography, changes in any one of these mechanisms could result in distributional changes over large areas. The topography and environmental history of the region has meant that local-scale patterns are, and have been, very important to the persistence of fire-sensitive biota.

Cycles of the wetting and drying, both seasonally, and on the larger time scales of the Quaternary, would have caused the expansion and contraction of what was identified as the high rainfall zone in Chapter 5 (i.e. > 1000 mm rainfall pa.). Such expansions and contractions would have allowed the colonisation of new areas of forest in wet periods, and would have acted as vicariance events as the landscape dried again. As argued in Chapter 6, decomposition of organic matter in Australia temperate forests is regulated by litter inputs and the decomposer community in conjunction with fluctuations in moisture. It is therefore logical to assume that there have been distinct patterns of organic matter decomposition operating in south-western Australian landscapes since the demise of the Miocene rainforests, and that patterns of terrestrial isopod distributions therefore must be in some way related to them. In other words, the patterns we see today reflect to some degree patterns of surface organic matter of the past. Superimposed upon both of these patterns is the insidious imprint of recent, exogenous disturbance.

I hypothesise that decomposition has been periodically driven by either (a) invertebrate and microbial communities, of which isopods are an important part, and moisture or by (b) leaching and fire. However, these changes will not have been universal across large parts of the landscape. Parts of the landscape will have seen frequent fire and some parts very infrequent. The relative size of the patches of a fire mosaic will have fluctuated throughout the Quaternary. Refugia have existed in places in the landscape that are moist and accumulate organic matter. The build up of organic material and differing decomposition regimes would lead eventually to detectable edaphic boundaries within the landscape. These boundaries would be influenced by and would influence local hydrological regimes. Hopkins et al. (1983) suggested that the presence of relictual species in very localised parts of the landscape implied that conditions are perhaps as dry now as any time in the recent past. Edaphic barriers have been important in the speciation of plants (Hopper, 1979; Hopkins et al. 1983), frogs (Wardell-Johnson & Roberts, 1996), and the endemic and relictual, freshwater crayfishes of the genus Engaewa (Horwitz & Adams, 2000). Edaphic barriers of a few kilometres are sufficient to

maintain geographic separation of species in Geocrinia (Wardell-Johnson & Roberts, 1996).

Changing fire regimes are certainly a fundamental part of climatic speciation mechanisms. All aspects of the fire regime have the potential to influence the periodicity of the removal of surface organic matter. A change to any of the four elements of a fire regime (frequency, intensity, season and area) has the potential to create vicariant process for moisture- and surface organic matter-dependent taxa. What is probably most important to terrestrial isopods populations is the spatial heterogeneity of fire at both small and large scales. Any of the four elements of a fire regime have the capacity to do this, but what is more important, and what is usually not considered in fire ecology, is the nature of the organic matter.

Fire regimes have not remained constant in south-western Australia through the Quaternary. Warmer periods, with greater rainfall and higher temperatures probably meant high organic matter productivity. Drier periods would have been cooler but moist in coastal areas. Fires would probably have been fewer and certainly less intense due to cooler conditions and sparser organic matter and vegetation. Southwestern Australia had a long history of fire prior to the arrival of Aboriginals (Bowman, 2003). The postulated skilful use of fire by Aboriginals to meet specific ends (Hallam, 1975) has undoubtedly resulted in altered fire regimes. All aspects of the regime are likely to have been influenced by Aboriginal burning but what is increasingly important would have been the area burnt. The scale at which fire was applied to the landscape and the sources of ignition would have changed. However, fire would not have been applied equally to all parts of the region. The central section of the jarrah forest, the south coast and karri forests were little used and little burnt (Hallam, 1975; Burrows, Ward & Robinson, 1995) except perhaps along major watercourses (Hallam, 1975), and there are few records of fires in these forest areas during early European settlement (Abbott, 2003).

Both seasonal and long terms cycles of aridity will have influenced profoundly the process of the accumulation and decomposition of organic matter. Bowman (2003) citing Kirkpatrick (1995) suggested that, were it not for the evolutionary pressure of fire in the wet sclerophyll forests of south Western Australia, the climate would support rainforest. Therefore, the presence of Gondwanan rainforest elements in the biota is pointing to the heterogeneous nature of fire in the landscape. Whilst fire may have been prevalent at the landscape scale there is much evidence of fire refuges throughout the landscape. The presence of a rich and endemic "fire adapted" flora doesn't imply the importance of fire as an evolutionary agent but the importance of a heterogeneous fire history.

In summary, surface organic matter is, and has been, central to the process of speciation of the region's Oniscidea and to the retention of highly significant relictual biotic elements

within the landscape. The southwest of Western Australian is considered to have subdued topography In such a landscape, which has remained unglaciated since the Permian, speciation boundaries of moisture-dependent taxa have been related to edaphic conditions. Surface organic matter has been accumulating in various parts of the landscape for at least the last 8 ka and in various cycles before that. The importance of local edaphic conditions is emphasised by the many climatic fluctuations experienced by the south west of the continent. The regional importance of moisture and the capacity of moist locations in the landscape to retain vulnerable species, for extremely long periods of time, through extended drought, was first summarised by Main and Main (1991) and has been refined and restated elsewhere (e.g. Hopper et al., 1996; Horwitz et al., 1997; 2003). Specific characteristics of sites in south-west Australia where Gondwanan elements might be found and conserved are:

1. Areas unaffected by salinisation;
2. High rainfall areas with short summer drought;
3. Topographically high south coastal areas subject to frequent mists, cloud and drizzle;
4 Areas adjacent to granite rocks from which water is shed;
5. Areas of impeded groundwater flow so producing winter wet swamps;
6. Streams with extensive fresh headwater swamps and year round flow;
7. Areas where vegetation can harvest water from fog or cloud by drip from leaves and stem flow e.g. tingle forest and south coast dunes and heath;
8. Areas with southern or south-west aspect which are thus sheltered from summer insolation e.g. valley slopes and wet valley floors;
9. Areas of intact forest canopy under which the characteristic understorey shrubs and herbs occur; and,
10. Springs and caves streams or other expressions of interstitial or groundwater.

The spatial and temporal patterns of organic matter decomposition of over a long period have been central to the evolution of the region's terrestrial isopods. Relatively moist and drier periods combined with ever-dynamic fire regimes would involve periodic shifts in the nature of decomposition to which invertebrate communities would have responded. Terrestrial isopods have been shown to make an important contribution to the decomposition of leaf litter. Through the digestion of organic matter and faeces, they contribute to the spatial distribution of fungal propagules and bacteria (Hassall et al., 1987). There are probably significant links to be established between the distribution of wet forest Oniscidea, patterns of decomposition and other important components of the relictual biota.

These hypothesized shifts in decomposition processes of surface organic matter are probably causing parallel changes in invertebrate decomposer communities. Small-scale ecological distributional boundaries of moisture-dependent decomposer organisms, such as terrestrial isopods are probably are the result of the temporal and spatial flux in decomposition processes. Therefore, I suggest the following categories be added to the list of site characteristics for the presence of likely Gondwanan taxa:

11. Other sites (at all scales) where organic material accumulates; and,

12. Other sites (at all scales) where decomposition processes have been driven by biotic communities for long periods without interruption.

8.5. SPECIATION PATTERNS

Early work in south-western Australia by Main and co-workers proposed a rich speciation in frog fauna by pluvial bridges to eastern Australia, allowing the entry into Western Australia of elements from the east (Paterson & James, 1973). Arid inter pluvial events subsequently then separated the species allowing speciation to occur. A view favoured at present, through the study of both plants (e.g. Hopper, 1979) and vertebrates (e.g. Roberts & Wardell Johnson, 1996), is one of localised speciation based largely on edaphic factors. The relationship of the terrestrial isopods of the region suggests a long period of separation. While definite phylogenetic relationships are yet to be established, many of the wet forest taxa appear to be ancient and endemic. There are probable generic relationships (e.g. Styloniscus) between taxa found in south-western Australia and in Tasmania, New Zealand, and much of the far southern hemisphere.

The biogeographic model presented earlier in the chapter concords well with other interpretations of the region. What is starkly different from other models is the clear distinction between the Northern and Southern Subregions. The Southern Subregion contains all the moist litter dependent Pseudolaureola and many of the litter dwelling Laevophiloscia species 2 and Styloniscus species 1 and 7. There are a few outliers of the more mobile taxa in the Northern Subregion indicating that distributions may have extended further north in the recent past. Diversity in the southern subregion is greatest in the far south and is comparable with that in the richer northern parts. It appears that terrestrial isopod fauna of the two subregions have largely different origins. There are fundamental differences at both the species and generic level. The Southern Subregion contains mostly surface organic matter-dependent wet forest taxa concentrated in the far south (Zone Ss) with related species persisting further north, due to the moisture retaining capacity of surface organic matter. In contrast, the overlapping nature of many local patterns in the northern subregion appears to be a result of the post speciation intermingling of taxa adapted to lower rainfall and seasonally drier conditions.

Accompanying these are relictual taxa, having persisted in damp patches in the landscape provided by the unique topography of the area Figure 8 5 shows three speciation models that attempt to explain the historical biogeography of the terrestrial isopods in south-western Australia The models include points of refuge (if appropriate) and the directions of geographical range expansion and contraction during wet and dry phases The models are explained in the following three subsections

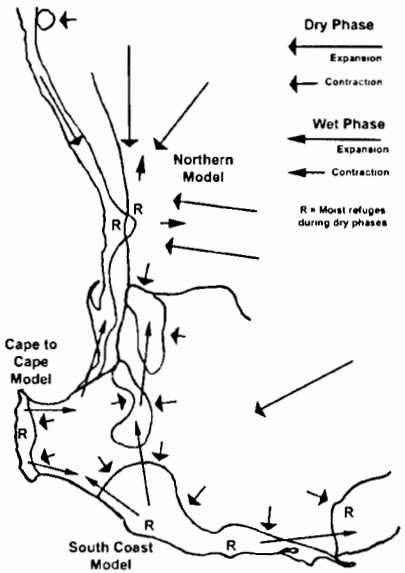

Figure 8 5 Three models, the Northern Model, the Cape to Cape Model and the South Coast Model, based on the expansion and contraction of species ranges during wet and dry phases, proposed to explain the biogeographical patterns of terrestrial isopods in south-Western Australia.

8.5.1. SOUTH COAST MODEL

A glance at the boundaries of Sn2, Sn3 and Ss1 suggest that the zones were recently connected The far south of the region is, and undoubtedly has been, an important refuge for moisture-dependent invertebrate fauna The majority of the wet forest fauna of the Jarrah forest Zones Sn2 and Sn3, appears to consist of species that have recolonised through the top of the Zone Ss1 into Sn3 and up into Zone Sn2 some time in the recent

past Zone Sn2 probably extended further north and has recently contracted The evidence for this exists in the form of outliers of Buddelundia species 5 at Mount Cooke (Figure 8 1 (▲)) and some outliers of regionally distributed taxa (e g Stylonisicus species 7 and Laevophiloscia species 2) found mainly in the southern wetter areas. There are also related species (e.g. Pseudolaureola new species 4) of the far south zone found in the south-eastern Zone Sn5. These are generally restricted to outlying forest patches The southeast Zone Sn5 is likely to be a significant centre for relictual fauna with local and highly restricted ranges.

The genus Pseudolaureola best highlights this proposed speciation model. There are three species in the far south, a species in the highest rainfall zone of the jarrah forest (Sn2) and a species found in Zone Sn3, midway between the two The species in Zone Sn2 and Sn3 may be the result of dispersal and speciation into wetter forests, as the climate became wetter, or by a drying climate creating a vicariant speciation of a previously more widely distributed species

Some interesting observations can be made about the character of spinal length. Assuming that the character of spinal length is not varying solely according to latitude and climate and represents phylogenetic origins, the following processes can be proposed. Dorsal spines are longest in areas of higher rainfall. They are longest in the high rainfall restricted Pseudolaureola new species 2 in the far-south zone of Ss1 second longest in the locally distributed P. wilsmorei and third longest in the restricted most northerly species, Pseudolaureola new species 1 in Zone Sn2 The variation in this character is accompanied by the reduction or loss of pleonal epimeral spines and sometimes pereonal epimeral spines. These characters suggest that Pseudolaureola new species 1 from Zone Sn2 in the high rainfall jarrah forest is more closely related to P wilsmorei from the Zone Ss than it is to its nearest geographical relative Pseudolaureola new species 5 found in Zone Sn3 Both Pseudolaureola new species 5 and new species 4 (Zone Sn5) have shorter spines and occur in lower rainfall. It therefore seems more likely that these species are the product of vicariance due to contraction of the wet forests and an evolutionary reduction in spines as a recent adaptation to more cryptic microhabitats

A phylogenetic analysis and cladogram of the Pseudolaureola would provide evidence to test this hypothesis This would be strengthened by a similar examination of the Stylonisicus The two genera are archetypal moisture-dependent wet forest genera and their speciation patterns are likely to best reflect patterns of fluctuating moisture within the region

8.5.2. CAPE TO CAPE MODEL

It is interesting to note that Zone Sn4, unlike Zones Sn 2, Sn3 and Sn5, has no endemic species of Pseudolaureola. A population of P. wilsmorei that occurs at the very southern tip of the zone shows some morphological differences from other populations. It was also found in littoral vegetation and soil of a freshwater swamp, a remarkably different microhabitat from other members of the genus. Other than the presence of an outlying population of Buddelundia species 6, there are few faunal connections to Zone Sn4. There is further evidence in the presence of different forms of the complex Pseudodiploexochus species 1, that short-range endemics occur here in associations with fine scale hydrological patterns that characterise the zone. Southern zone Gondwanan elements of the isopod fauna in the Cape to Cape Zone (Sn4) are probably not in the forests but elsewhere. Local freshwater seepages and caves are probably critically important to these species. Whilst the Cape to Cape region is also an important refuge for moisture-dependent species, in common with other moisture-dependent invertebrates they probably remain largely restricted. It may be that they are less capable of dispersal by means of surface organic matter than those from the south coast, or that surface significant dispersal barriers have persisted between Zone Sn3 and Sn4 during wetter periods.

Whereas species of Pseudolaureola seem to have colonised parts of the wet jarrah forest from the wetter forests further south, some species, concentrated in the Cape to Cape (Zone Sn4) region, appear to have expanded their distribution northward via the coastal woodlands. Examples of such species include Hanoniscus new species, Australoniscus new species 1 and Buddelundia nigripes. B. nigripes appears to have colonised parts of the Jarrah forest Zones Sn3 and Sn2. Unlike the north of the region, the bioregional boundary between the Jarrah Forest and Swan Coastal Plain appears much less defined at this point. The jarrah-dominated woodlands (prior to clearing) of the Pinjarra plain would have extended much further toward the coast at this point and conceivably connected with the coastal tuart woodlands of western Swan Coastal Plain allowing dispersal to take place.

The Cape to Cape region is an area of important relictual fauna based on fine scale hydrological regimes (e.g. Horwitz & Adams, 2000). The true nature of the terrestrial isopod fauna has not yet been revealed. A more intensive sampling strategy is needed. While there has probably been some expansion of taxa from the Cape to Cape region, it is likely that it has been an important centre of incipient speciation, the evidence of which will probably be revealed by further collecting and by finer taxonomic resolution of genera like Pseudodiploexochus.

8.5.3. NORTHERN MODEL

The Northern Model is perhaps the most complex of the three. In the Northern Zone there is bioregional specificity and clear associations with soil type, few true moist litter dependent taxa, other than perhaps some coastal woodland species. The region is characterised by a high richness of locally distributed Armadillidae and a range of cryptic species in other families persisting because of important landscape features. Both Hanoniscus tuberculatus and H. monodi are confined to swamps or creeks while Cubaris species 1 is found in low lying damp spots within the landscape. There are also single locality species, such as Styloniscus sp 5, associated with the Darling Scarp. Relictual species are likely to have persisted in the landscape by means other than surface organic matter. As was proposed by the South Coast Model, many of the wetter forest taxa appears to have contracted southward.

Bioregional specificity may have resulted from two processes. The first involves eustatic changes separating upland parts of the Swan Coastal Plain from the Darling Scarp. Without a cladistic analysis interpretations are difficult but various hypotheses can be constructed. Taxa would occupy much of the favourable parts of the Swan Coastal Plain and Jarrah forest when sea levels were lower. As sea levels rose, parts of the Swan Coastal Plain would become inundated by marine waters having the vicanant effect of creating isolated populations on islands. At the junction of the Spearwood and Bassendean landform systems there is a chain of shallow wetlands that are the surface expressions of groundwater. It is likely that, during the climatic changes of the Quaternary, parts of the Bassendean dunes would have either been very dry areas with well drained sandy soils, even desert like according to Glassford and Killigrew (1976) and Semeniuk (1995), or flooded. Such a landform presents a significant edaphic barrier to the dispersal of the Oniscidea and helps maintain species barriers between the coastal parts of the Swan Coastal Plain and the Darling Scarp. Even as sea levels dropped again, biogeographical barriers would be retained. Successive rising and falling of sea-levels has contributed to the distribution and speciation of some species in the freshwater crayfish genus Engaeus in south-eastern Australia (Horwitz, 1988). A second explanation is that species have colonised the northern part of the Swan Coastal Plain from the north following the drop in a sea level during the Holocene. This is probably true for many of the more xeric Buddelundia such as B. cinerascens which is found much further north (Dalens, 1992)

The richness of the Perth area has been highlighted by a long collection history and is probably related to the presence of the Swan River estuary. The original fringing woodland and swamp vegetation would have provided a link between the coastal zone Nw2 and the Zone Ne1 on the Darling Range. The distribution of the swamp-dwelling Hanoniscus tuberculatus throughout swamps on the Swan Coastal Plain and in eastern

parts of the Darling Range suggests a prehistonc period when swamplands and damplands were more extensive throughout both the Swan Coastal Plain and the Darling Range The notion of more extensive and connected wetland systems is supported by the fact that there is disjunction with species found in wetlands north of Perth and in the Warren Bioregion (Judd, Horwitz & Jones, 1999), most easily recognisable in the genus of aquatic amphipod Perthia (Perthidae) and also in the fish Galaxiella nigrostriata, G. munda and G. balstoni (Morgan et. al., 1996). This, and similar disjunctions in forest wetland invertebrate taxa, implies a wetter time when wetland systems connected the Perth region to the wetter south coast

The Armadillidae show a classic Gondwanan distribution and are especially rich in Australia (Schmidt, 2002b). The north of the region and semi arid parts in general (Judd, unpublished data) are dominated by the genus Buddelundia. This genus is found mainly in Western Australia although there are species recorded from South Australia (Wahrberg, 1922, Warburg, 1965; Vandel, 1973a), New South Wales (Vandel, 1973a) and Indonesia (S. Taiti, pers. Comm., 2001). It is adapted to the drier conditions of the semi arid areas, probably facilitated in part by the unique arrangement of the pleopods. It is certainly of Australian origin and is likely to have arisen following the demise of the Pliocene rainforest and diversified during the Quaternary along with the rise of the eucalypts and other sclerophyllous plants. Buddelundia is the most specious of any genera of Oniscidea in Western Australia (if not Australia) and is represented in all parts of the landscape. The distribution B. nitidissima, the most widely distributed species in the region, is concentrated in the more open woodlands of the Northern Subregion but it appears to have expanded westward and southward. Given the nature of surface organic matter and climatic vagaries of the region, it is easier to find dry spots in wet landscape than it is to find wet spots in a dry one. It is therefore easier for xeric taxa to colonise wet forest than it is for hydrophilic taxa to colonise semi arid areas B nitidissima is the only species with a distribution centred in the Northern Subregion that occurs extensively in the Southern Subregion. Its expansion into much of the jarrah forest may be an indication that drier climatic conditions are prevailing.

A cladistic analysis of the Buddelundia would provide for a much clearer understanding of the Northern speciation model It would assist in understanding the causes of bioregional specificity and the relationships between the northern subregion and the rest of Western Australia. The fact that a primitive and an advanced group are present (Dalens, 1992), probably as subgenera, and that they are distributed throughout Western Australia, makes them an ideal subject for delineating patterns at all scales.

8.5.4. TESTING THE MODELS

The interpretation of regional biogeography is hindered at this stage by a lack of phylogenetic data. As shown by proposed speciation models, further taxonomic work should reap some rich rewards. Harvey (1996) pointed out that, central to understanding the true relictual nature of the fauna of the southwest, was a clearer understanding of the wider biogeographic affinities of small organisms with limited dispersal capacities derived from detailed studies. The recognition of ancient clades, he added, that have small distributions, raises questions about their conservation. Within the both the Southern and Northern Subregions there are examples of cryptic species that have probably persisted in small ranges throughout the period of recent climatic change. While the recognition of these species is critical in itself, fine scale patterns are illustrated effectively by the very small, primitive Styloniscus. Green (1971, p 73) characterised the Tasmanian Styloniscidae as inhabiting "damp forest litter" something that is paralleled in their occurrence in Western Australian. Styloniscus species 1 and species 7 represent species complexes. There are also three, single locality primitive forms found in each of the Zones Ne, Sn and Ss suggesting the long-term persistence of short-range endemics. These were associated with leaf litter in the south of the region and with granitic features of the Darling Scarp. The potential number of species, the Gondwanan nature of the group the distributional patterns presented in Chapter 5, suggests that greater taxonomic discrimination and cladistic analysis of the region's Styloniscidae would result in a much clearer understanding of the origin of the biogeographic patterns of the region.

The speciation models shown in Figure 8.5 have set down some very clear taxonomic priorities. The further elucidation of three genera Pseudolaureola, Buddelundia and Styloniscus would be useful as it would provide examples of taxa existing with a range of moisture regimes, occurring in well-defined biogeographical boundaries at a range of distributional scales. Fortunately, they are likely to be the easiest groups to deal with. Styloniscus has been examined relatively recently for Tasmania and at an appropriate level of detail (Green, 1971), while the other two genera are distinct enough to circumvent the generic malaise that is the Australian Armadillidae.

Given the dependence on surface organic matter and moisture shown in Chapter 7, the conservation of terrestrial isopods must be addressed. Small-scale endemics are obviously the result of isolating processes, such as climate change or changed fire regimes, producing relictual populations. It is hard to argue otherwise given a dependency upon moisture and the climatic history of the region. Species with small distributions, persisting and moist microhabitats, in a seasonally dry climate, have a perilous existence Such species are present throughout the region. There are undoubtedly more taxa yet to be found and additional short range fine scale patterns will

certainly be elucidated by further taxonomic endeavour. Further taxonomic work would therefore be underpinned by clear conservation imperatives.

8.6. FATE OF THE FAUNA

The ultimate fate of the relictual Oniscidea in southwest Australia is irreversibly linked to the presence of surface organic matter and moisture. Their persistence in seasonally hot and dry landscapes depends largely upon the landscape's capacity to retain moisture for longer periods of time during seasonal drought. In many places this is only made possible because of vegetative cover and organic matter. Changes in the supply, accumulation and the type of organic matter are likely to influence the degree to which sensitive taxa are buffered against disturbance events. Therefore, moist microhabitats are critical to the conservation of biodiversity because they provide for a biologically and taxonomically significant component of regional biodiversity.

The presence of small-scale forest dwelling endemics is threatened by broad-scale manipulation of organic matter and the populations of more widely distributed species are likely to be fragmented, making each subsequent population vulnerable to local disturbances. It is possible that the present climate is nearly the most arid since the late Pleistocene (Hopkins, Keighery and Marchant, 1983) and there is evidence that it is likely to become drier (Wright, 1992; Indian Ocean Climate Initiative Panel (IOCIP, 2002). In terms of a precautionary approach to the conservation of the region's terrestrial isopods, it should be assumed that both of these statements are true. If the climate were to become wetter, the more vulnerable wetter forest taxa may be less threatened, although there is little scope for range expansion at the landscape scale because their distribution is now confined to the fragmented and modified extant forest estate.

The frequency of fire in the landscape is of paramount concern since it has been increasing throughout Quaternary and, despite relatively short-term cycles, appears to be increasing. At present there are not enough data, consensus or resolution in the Holocene climate to understand the true nature of climatic and fire cycles in the region's landscape. Therefore, today's society is still learning how to manage a flammable land, further emphasising the need for a precautionary approach. What is necessary, is to slow the rate of change and to create new ecological equilibria (Bowman, 2003).

The forests of the region, which harbour much of the region's terrestrial isopod diversity and probably the most significant relictual components, have been heavily modified. Nearly all the jarrah forest has been harvested once, about half the jarrah forest and wandoo woodlands have been harvested twice and some areas have been harvested five times since 1829 (Heberle, 1997) The karri forest has a much more recent history of logging and, according to Heberle (1997), most of it has only been logged once The

result of these operations has been to replace a mature forest with regrowth forests of a different structure (Cannon, et al, 1994; Zeigler, 2000), canopy characteristics (Aber, 1979) and probably plant species richness (Ross, Fox & Fox, 2002). In more open Western Australian woodland communities, fire can convert the woodland to mallee-heath, causing major vegetational structural disjunctions within the landscape (Hopkins & Robinson, 1981). Such structural changes, whatever their magnitude, will certainly have affected moisture regimes on the forest floor, particularly the removal of canopy cover (Canham, et al , 1990; Breshears et al., 1998). The nature of surface organic matter will have changed dramatically, favouring much smaller coarse woody debris instead of the large logs that would once have fallen to the forest floor. These processes will have affected profoundly two things: firstly, the area of contact between the soil and the log is reduced and, secondly, the distribution and accumulation of litter fall will differ.

Soil under logs is sheltered from both precipitation and sunlight. This serves to regulate soil moisture and temperature, providing a buffer for taxa against both extremely dry and wet conditions. Litter also builds up under logs, and the rounded nature of logs means that litter can accumulate under logs and be shaded by it. Depending upon the aspect and slope of the forest floor, the litter may be protected from sunlight or from prevailing wind and rains or both. In some circumstances the litter or soil may never be wetted or exposed to sunlight, thereby creating a contrasting moisture regime in the surrounding soil at the micro-scale. Logs produced by the senescence and fall of mature jarrah and marri trees are now virtually absent from the jarrah forest (pers. obs). Where I have encountered them I have often found restricted taxa either associated directly with them or with the litter that builds up next to them (e.g. sites 75, 92). It is principally the size of log that determines the interface with the soil and consequently the spatial availability of suitable microhabitat.

The continued decay of old and sizable logs is also important to forest biodiversity (Lindenmayer et al., 2002). Relictual species in particular inhabit rotting logs. Barclay, Ash and Rowell (2000) found that populations of the log-dwelling Onycophoran Euperipatoides rowelli were related to both log volume and moisture content. The species was most abundant in larger logs and preferred wetter logs. In fact, the authors concluded that logs could only support large populations after forty-five years of decay. Decayed, moist logs are recognised as significant sources of biodiversity (Harmon, et al. 1986). Although there are no historical data to demonstrate it, or suitable patches of unmodified forest in which to test it, it can be contested that the size and distributions of logs has changed considerably in Western Australia forests. Logs following logging operations are usually stockpiled at the edge of a coupe. This facilitates drying, intense and prolonged burning, and, since many of the logs have no contact at all with the soil (Plate 8.1), they therefore have little capacity to be colonised by much of the decomposer community.

Management of Western Australian forests has traditionally stemmed from the perception of homogenous areas dominated by a single, commercially important, tree species (Wardell-Johnson & Horwitz, 1996). These are principally E. marginata, E. diversicolor for timber, and E. diversicolor and E. calophylla for woodchips, and are species that are relatively widely distributed. Therefore, management strategies were traditionally formulated at the bioregional or sub bioregional scale. Forest management is now based on the subdivision of the forest estate into management units or blocks 5-15 000 ha in size. The administrative boundaries of blocks are not based upon edaphic factors but are simple delineations based only partly upon natural features. The creation of these management units has led to compartmentalised forest in which broad-scale management prescriptions can be applied on a block by block basis. Within any given management unit there may a complex history of different silvicultural techniques designed to promote the growth of merchantable timber (Conservation Commission, 2002). Therefore, the most profound effect upon short scale moisture-dependent organisms is to create discrete populations within forest block boundaries.

Plate 8.1. An artificial distribution of logs following logging in Zone Ne1, near Mount Dale. Logs are concentrated in one place, piled up and have little interaction with the soil substrate. This is in contrast to old trees that would fall to forest floor often resulting in the partial burial in the soil. The area of interaction between the soil and log is reduced. This reduces the availability, continuity and properties of the log/soil microhabitat and will influence the subsequent accumulation of surface organic matter. When the coupe is burnt for regeneration purposes, elements of the fire regime, such as area and intensity will probably also differ.

South-western Australia is in a climatically-drying phase with drier winters for the last twenty years and continuing into the future (IOCIP, 2002). Added to this, forest fragmentation is in itself a great drying agent, thereby enhancing an already threatening

process. Roads and firebreaks are constructed around forest blocks and are kept free from the accumulation of surface organic matter, to prevent the spread of fire and to allow for the passage of vehicles. The dispersal of short scale endemics, and to a lesser degree the regions terrestrial isopods as a whole, will be restricted to moist seasons of the year in conditions where there is spatial continuity of leaf litter. Some taxa may also require continuity in log distribution. Therefore, block boundaries serve to create isolated populations.

The reduced presence of old and large trees must not overlooked; tree bark of some species although notably not jarrah, is utilised by terrestrial isopods and other invertebrates. Baehr (1990) noted the richness and relictual nature of invertebrate fauna under the bark of large eucalypts. He highlighted the importance of the microhabitat as a refuge from both drought and fire. A subcorticular existence offers high humidity, low thermal conductivity of the bark and a great diversity of niches, and Baehr (1990) noted high endemism in the subcorticular fauna of western and northern Australia. There have been no studies of subcorticular fauna in Western Australian forests but, as demonstrated here for terrestrial isopods, the microhabitat is clearly important. The distribution of the fauna is likely to be influenced by the age and size of the trees. Therefore, anything that changes the size classes of trees, such as periodic logging, is likely to affect the distribution of subcorticular fauna. In the case of karri, clearfelling and burning probably eliminates systematically some of the most moisture-dependent species from all but old-growth forest.

Long periods of litter build up, tree senescence and tree death are central to the persistence of terrestrial isopods in the landscape. Very recent changes, land clearing, marked changes to forest structure and to the nature of surface organic matter, particularly the presence of very large and old logs, operating at a regional scale, are now responsible for the patchy and scarce distribution of relictual elements in the wetter parts of the jarrah forest. Natural climate variation has created zones in which the role of surface organic matter differs. The effect of the very recent clearing and intensive utilisation of Western Australia forests has probably been to create large homogenous landscape units, the shrinking of the wetter zones and the expansion of the low diversity Zone Sn1. There is evidence of this happening already. There is a great deal of variation at the site scale throughout the jarrah forest At many sites, surface organic matter and logs are scarce; point diversity is very low because only widely distributed, often generalist taxa are present. Since distributional patterns are driven by microhabitat utilisation, anything that influences microhabitat must influence distribution Much of the patchiness in the distribution of many species is related to variability in site conditions due to both intrinsic landscape variation and the results of recent human activities. Short-range endemics do not have ability to adapt to the imposed landscape mosaic at the current temporal and spatial scales of the current management regime. If threatening

processes continue to be applied at the broad scale, block by block, there will be an incremental loss of populations until species disappear.

The question of appropriate spatial and temporal scales for the application of management techniques such as prescribed burning is important. The answer is often sought by determining fire frequency from some point in the past (e g Ward, Lamont & Burrows, 2001). While some studies allude to determining historical fire regimes, at best, they can only determine the historical frequency of fire for a limited area, sometimes for a single plant, and over an extremely limited period of time. It is not possible to reconstruct a fire regime. The area, which fires burnt, or failed to burn, the duration and the intensity with which they burnt, are not detectable for anything other than a very recent fire Probably what is more critical, nothing can be learned about the historical nature and distribution of fuel type

A far easier and more worthwhile task is to determine where fire has been absent from the landscape This is indicated by the presence of fire sensitive species such as the highly moisture-dependent component of the terrestrial isopods fauna. Clearly, there are no terrestrial isopods that are adapted to fire. Each species has relied, to some degree, upon surface organic matter, either to survive individual fire events or to recolonise burnt areas, and build up population numbers and distributional boundaries robust enough to survive the next fire. In some circumstances, this may not happen. This can be considered a vicariance event.

The evolution of the group in the region has encompassed many different fire regimes with many different surface organic matter fuel types. There is clearly a balance of some sort between the nature of surface organic matter, the behaviour of fire and the persistence of decomposer communities. A change in fire regime as well as, or perhaps associated with, climatic change must be viewed as either a vicariance event, or conversely as a dispersal opportunity. The distributions of all species are governed by such changes. A successful fire regime is not one abstracted from the past but one that preserves what has persisted through all regimes of the past.

The terrestrial isopod fauna, which contain a conspicuous relictual component, provide a valuable insight to the evolutionary processes of the past. There is still much to be learned about their phylogeny and ecology. If this is to be achieved, significant areas of the forested part of south-west Australia must be kept with canopy intact and with surface organic matter accumulating for very long periods.

REFERENCES

Abbott, I. (1984). Changes in the abundance and activity of certain soil and litter fauna in the jarrah forest of Western Australia after a moderate intensity fire. *Australian Journal of Soil Research*, 22, 463-469.

Abbott, I. (1985). The influence of some environmental factors on indigenous earthworms in the northern jarrah forest of Western Australia. *Australian Journal of Soil Research*, 23, 271-290

Abbott, I (1995) Prodromus of the occurrence and distribution of insect spiders in the forested parts of south-west Western Australia *CALMScience*, 1, 365-464

Abbott, I , Burbidge, T , Strehlow, K , Mellican, A. and Wills, A (2003) Logging and burning impacts on cockroaches, crickets and grasshoppers and spiders in jarrah forest, Western Australia. *Forest Ecology and Management*, 174, 389-399

Abbott, I. & Burrows, N (1998) Biodiversity conservation in the forests and associated vegetation types of southwest Western Australia *Australian Forestry*, 62, 27-32.

Abbott, I. & Chnstensen, P. (1994) Applications of ecological and evolutionary principles to forest management in Western Australia,. *Australian Forestry*. 57, 109-122.

Abbott, I. & Christensen, P. (1996). Objective knowledge, ideology and the forests of Western Australia. *Australian Forestry*, 59, 206-212.

Abbott, I., van Heurck, P. & Wong, L. (1984). Responses to long-term fire exclusion physical, chemical and faunal features of litter and soil in a Western Australian forest. *Australian Forestry*, 47, 237-242.

Aber, J. D. (1979). Foliage-height profiles and succession in northern hardwood forests. *Ecology*, 60, 18-23

Aljetlawi, A. A., & Nair, G A. (1994). Breeding and population biology of Armadillo officinalis (Isopoda: Oniscidea) in Benghazi, Libya. *Journal of Arid Environments*, 27, 241-255.

Anderson, J. M. (1988) Spatiotemporal effects of invertebrates on soil processes. *Biology and Fertility of Soils*, 6, 216-227.

Andrew, N., Rodgerson, L. & York, A. (2000). Frequent fuel-reduction burning: the role of logs and associated leaf litter in the conservation of ant biodiversity. *Austral Ecology*, 25, 99-107.

Araújo, M. B (2002). Biodiversity hotspots and zones of ecological transition. *Conservation Biology*, 16, 1662-1663.

Araújo, P. B. & Leistikow, A. (1999). Philosciids with pleopodal lungs from Brazil, with a description of a new species (Crustacea, Isopoda). *Contributions to Zoology*, 68, 109-141.

Archer, M (1996) Refugial vertebrates from the Miocene rainforests of Western Australia. where are they? In S. D. Hopper, et al. (Eds.), *Gondwanan Heritage: past, present and future of the Western Australian biota* (pp. 100-03). Chipping Norton: Surrey Beatty & Sons.

Ashton, D. H. (1975). Studies of Litter in Eucalyptus regnans forests. *Australian Journal of Botany*, 23, 413-433.

Backhouse, J. (1993). Holocene vegetation and climate record from Barker Swamp, Rottnest Island, Western Australia. *Journal of the Royal Society of Western Australia*, 76, 53-61.

Baehr, M. (1990) The carabid community living under the bark of Australian eucalypts. In N. E. Stork (Ed), *The Role of Ground Beetles in Ecological and Environmental Studies*. (pp 3-11) Andover Intercept

Baker, W. H. (1913). On three species of isopod Crustacea found in the nest of ants. *Transactions of the Royal Society of South Australia*, 37, 116-120.

Balla, S. & Davis, J. A. (1993). Managing Perth's wetlands to conserve aquatic fauna. *Wetlands of the Swan Costal Plain, Volume 5*. Perth: Water Authority of Western Australia and Environmental Protection Authority of Western Australia.

Barclay, S. D., Ash, J. E. & Rowell, D. M. (2000). Environmental factors influencing the presence and abundance of a log-dwelling invertebrate Euperipatoides rowelli (Onychophora: Peripatopsidae). *Journal of Zoology, London*, 250, 425-436.

Barnard, K. H. (1932). Contribution to the crustacean fauna of South Africa no.11, terrestrial isopods. *Annals of the South African Museum*, 30, 179-388.

Barnard, K. H. (1960). Terrestrial Isopods from the Transvaal. *Annals of the Natal Museum*. 15, 45-55.

Barnes, H. M. (1934). Cubaris spenceri, A new terrestrial isopod from the Northern Territory of Australia. *Journal of the Royal Society of Western Australia*, 20, 63-70.

Bayly, I. A. E. (1982). Invertebrate fauna and ecology of temporary pools on granite outcrops in southern Western Australia. *Australian Journal of Marine and Freshwater Research*, 33, 599-606.

Bayly, I. A. E. (1992). The micro-crustacea and physicochemical features of temporary ponds near Northcliffe, Western Australia. *Journal of the Royal Society of Western Australia*, 75, 99-106.

Beard, J. S. (1979). Phytogeographic regions. In J. Gentilli (Ed.), *Western Landscapes* (pp. 107-121). Perth: University of Western Australia Press.

Beard, J. S. (1980). A new phytogeographic map of Western Australia. *Western Australian Herbarium Research Notes*, 3, 37-58.

Beard, J. S. (1981a). The history of the phytogeographic region concept in Australia. In A. Keast (Ed.), *Ecological biogeography of Australia* (Vol. 1, pp. 335-354). The Hague: Dr W Junk Publishers.

Beard, J. S. (1981b). *The vegetation of the Swan area*. Vegetation Survey of Western Australia 1:1 000 000 Series No. 7 map and explanatory notes. Nedlands: University of Western Australia Press.

Beard, J. S. (2001). Short Note: A historic vegetation map of Australia. *Austral Ecology*, 26, 441-443.

Beard, J. S., Chapman, A. R. and Gioia, P. (2000). Species richness and endemism in the Western Australian flora. *Journal of Biogeography*, 27, 1257-1268.

Berry, P. F. & Christie, G. (2002). Fauna collections databases in the Western Australian Museum. *Journal of the Royal Society of Western Australia*, 85, 143-145

Birk, E. M. & Bridges, R. G. (1989). Recurrent fires and fuel accumulation in even aged blackbutt (Eucalyptus pilularis) forests. *Forest Ecology and Management*, 29, 59-79.

Bowley, E. A. (1935). A survey of the Oniscoid genus Phalloniscus Budde-Lund with a description of new species. *Journal of the Royal Society of Western Australia*, XXI, 45-73.

Bowman, D. M. J. S. (2003). Australian landscape burning: a continental and evolutionary perspective. In I. Abbott & N. Burrows (Eds.), *Fire in ecosystems of south-western Australia: impacts and management* (pp. 107-118). Leiden: Backhuys Publishers.

Breshears, D. D , Nyhan, J. W., Heil, C. E. & Wilcox, B. P. (1998). Effects of plants on microclimate in a semiarid woodland: Soil temperature and evaporation in canopy and intercanopy patches. *International Journal of Plant Sciences*, 159(6), 1010-1017.

Brown, J. H., Stevens, G. C. & Kaufman, D. M. (1996). The geographic range: size, shape, boundaries and internal structure. *Annual Review of Ecology and Systematics*, 27, 597-623.

Brown, S., Jiangming, M., McPherson, J. K. & Bell, D. T. (1996). Decomposition of woody debris in Western Australian forests. *Canadian Journal of Forest Research*, 26, 954-966.

Budde-Lund, G. (1912). Oniscoidea, nachglassenes fragment. In W. Michaelsen & R. Hartmeyer (Eds.), *Die fauna Sudwest-Australiens* (Vol. 4, pp. 17-44). Jena: Fischer.

Bunn, S. E. (1983). Termite (Isoptera) fauna of jarrah forest in the Wagerup-Willowdale region, Western Australia: relevance to the rehabilitation of bauxite mines. *Forest Ecology and Management*, 6, 169-177.

Bunn, S. E. & Davies, P. M. (1992). Community structure of the macroinvertebrate fauna and water quality of a saline river system in south-western Australia. *Hydrobiologia* 248: 143-160.

Bunn, S. E., Edward, D. H. & Loneragan, N. R. (1986). Spatial and temporal variation in the macroinvertebrate fauna of streams of the northern jarrah forest, Western Australia: community structure. *Freshwater Biology*, 16, 67-91

Bunn, S. E. & Green, A. J. A. (1982). Oniscoidea (Crustacea: Isopoda) from Rottnest Island, Western Australia. *Journal of the Royal Society of Western Australia*, 65, 147-151.

CALM (1987a). *Regional Management Plan 1987-1997, Central Forest Region*. Como: Western Australian Department of Conservation and Land Management.

CALM (1987b). *Regional Management Plan 1987-1997, Northern Forest Region*. Como: Western Australian Department of Conservation and Land Management.

CALM (1987c). *Regional Management Plan 1987-1997, Southern Forest Region*. Como: Western Australian Department of Conservation and Land Management.

CALM (1992). *Management strategies for the south-west forests of Western Australia. A review. Draft - February 1992*. Como: Western Australian Department of Conservation and Land Management.

CALM (1995). *Strategic Plan 1995*. Como: Western Australian Department of Conservation and Land Management, Science and Information Division.

Calver, M. C. & Dell, J. (1998a). Conservation status of mammals and birds in southwestern Australian forests. II. Are there unstudied, indirect or long-terms links between forestry practices and species decline and extinction. *Pacific Conservation Biology*, 4, 315-325.

Calver, M. C. & Dell, J. (1998b). Conservation status of mammals and birds in southwestern Australian forests. I. Is there evidence of direct links between forestry practices and species decline and extinction? *Pacific Conservation Biology*, 4, 296-314.

Calver, M. C., Dickman, C. R., Feller, M. C., Hobbs, R. J., Horwitz, P., Recher, H. F. & Wardell-Johnson, G. (1998). Towards resolving conflict between forestry and conservation in Western Australia. *Australian Forestry*, 61, 258-266.

Calver, M. C., Hobbs, R. J., Horwitz, P. & Main, A. R. (1996). Science principles and forest management: a response to Abbott and Christensen. *Australian Forestry*, 59, 1-6.

Canham, C. D., Denslow, J. S., Platt, W. J., Runkle, J. R., Spies, T. A., & White, P. S. (1990). Light regimes beneath closed canopies and tree-fall gaps in temperate and tropical forests. *Canadian Journal of Forest Research*, 20, 620-631.

Cannon, C. H., Peart, D. R., Leigton, M., & Kartawinata, K. (1994). The structure of lowland rainforest after selective logging in West Kalimantan, Indonesia. *Forest Ecology and Management*, 67, 49-68.

Channell, R. & Lomolino, M. V. (2000). Trajectories to extinction: spatial dynamics of the contraction of geographical ranges. *Journal of Biogeography*, 27, 169-179.

Chilton, C. (1901). The terrestrial isopoda of New Zealand. Transactions of the *Linnean Society of London (Second Series, Zoology)*, 8, 99-152.

Chilton, C. (1910). Additions to the terrestrial isopoda of New Zealand. *Transactions of the New Zealand Institute*, 42, 286-91

Chilton, C. (1915a). Deto, a subantarctic genus of terrestrial Isopoda. *Zoological Journal of the Linnean Society (London)*, 32, 435-56.

Chilton, C. (1915b) Some terrestrial isopods from New Zealand and Tasmania, with descriptions of a new genus. *Zoological Journal of the Linnean Society (London)*, 32, 417-27.

Chilton, C. (1917). Notes on Australian isopoda. *Transactions of the Royal Society of South Australia*, 41, 391-404.

Chilton, C. (1920). On a new isopodan genus (Family Oniscidae) from Lake Corangamite, Victoria. *Proceedings of the Linnean Society of New South Wales*, 44, 723-734.

Christensen, P. (1982). The distribution of Lepidogalaxias salamandroides and other small fresh-water fishes in the lower south-west of Western Australia. *Journal of the Royal Society of Western Australia*, 65, 131-141.

Christensen, P. E. S. (1992). *The Karri Forest: Its conservation significance and management.* Perth: Department of Conservation and Land Management, Western Australia.

Christensen, P., & Abbott, I. (1989). Impact of fire in the eucalypt forest ecosystem of southern Western Australia: a critical review. *Australian Forestry, 52*, 103-121.

Choromanska, U, & DeLuca, T. H. (2002). Microbial activity and nitrogen mineralization in forest mineral soils following heating: evaluation of post-fire effects. *Soil Biology and Biochemistry*, 34, 263-271.

Churchill, D. M. (1959). Late Quaternary eustatic changes in the Swan River district. *Journal of the Royal Society of Western Australia*, 42, 53-55.

Churchill, D. M. (1968). The distribution and prehistory of Eucalyptus diversicolor F. Muell., E. marginata Donn ex Sm. and E. callophylla R. Br. in relation to rainfall. *Australian Journal of Botany*, 16, 125-151.

Claridge, A. W., Barry, S. C., Cork, S. J. & Trappe, J. M. (2000). Diversity and habitat relationships of hypogeous fungi. II. Factors influencing the occurrence and number of taxa. *Biodiversity and Conservation, 9*, 175-199.

Clarke, E, de C. (1926). Natural regions in Western Australia. *Journal of the Royal Society of Western Australia*, 12, 117-132.

Cody, M. L. (1975). Towards a theory of continental species diversity: Bird distributions over Mediterranean habitat gradients. In M. L. Cody and J. M. Diamond (Eds.) *Ecology and evolution of communities* (pp. 214-257). Cambridge: Harvard University Press.

Collett, N. G. (1999). Effects of three short rotation prescribed fires in spring on surface-active arthropods in dry sclerophyll eucalypt forest of west-central Victoria. *Australian Forestry*, 62, 295-306.

Collett, N. G., Neumann, F. G. & Tolhurst, K. G. (1993). Effects of two short rotation prescribed fires in spring on surface-active arthropods and earthworms in dry sclerophyll eucalypt forest of west-central Victoria. *Australian Forestry*, 56, 49-60.

Commonwealth of Australia & the State of Western Australia. (1998). *Comprehensive regional assessment, a regional forest agreement for Western Australia.* Canberra: Commonwealth and Western Australian Regional Forest Agreement Steering Committee.

Conservation Commission of Western Australia. (2002). *Draft forest management plan.* Perth: Conservation Commission of Western Australia.

Conservation Commission of Western Australia. (2003). *Proposed forest management plan*. Perth: Conservation Commission of Western Australia.

Cox, C. B. (2001). The biogeographic regions reconsidered. *Journal of Biogeography*, 28, 511-523.

Cranston, P. S. & Naumann, I. D. (1991). Biogeography. In I. D. Naumann (Ed.) *The insects of Australia* (pp. 180-97) (2nd Edition). Melbourne, Melbourne University Press.

Craw, R C., Grehan, J. R. & Heads, M. J. (1999). *Panbiogeography: tracking the history of life*, Oxford biogeography series No. 11. New York: Oxford University Press.

Crisci, J. V. (2002). The voice of historical biogeography. *Journal of Biogeography*, 28, 157-168.

Crisp, M. D., Laffan, S., Linder, H. P. & Monro, A. (2001). Endemism in the Australian flora. *Journal of Biogeography*, 28, 183-198.

Curry, S. J., Humphreys, W. F., Koch, L. E. & Main, B. Y. (1985). Changes in arachnid communities resulting from forestry practices in karri forest, south-west Western Australia. *Australian Forest Research*, 15, 469-480.

Dalens, H. (1992). Oniscidea (Crustacea: Isopoda) from caves of Cape Range in Western Australia. I. The genus Buddelundia. *Records of the Western Australian Museum*, 16(1), 87-102.

Dalens, H. (1993). Two new genera of terrestrial isopods (Crustacea: Isopoda: Oniscidea) from north-western Australia. *Records of the Western Australian Museum*, 16, 257-267.

Dalens, H. (1998). Isopodes terrestres de Nouvelle-Caledonie. II. Sur une nouvelle espece du genre Pseudolaureola (Crustacea, Oniscidea). *Zoosystema*, 20, 93-100.

De Laeter, J. R. & Libby, W. G. (1993). Early Palaeozoic biotite Rb-Sr dates in the Yilgarn Craton near Harvey, Western Australia. *Australian Journal of Earth Sciences*, 40, 445-53.

Dell, B. & Havel, J. J. (1989). The Jarrah Forest, an introduction. In B. Dell (Ed), *The Jarrah Forest* (pp. 1-10). Dordrecht: Kluwer Academic Publishers.

Diels, L. (1904). *Die pflanzenwelt von West-Australien südlich des Wendekreises*. Vol. 7 of vegetation der Erde. Leipzig: Engelmann.

Dodson, J. R. & Lu, J, J. (2000). A late Holocene vegetation and environment record from Byenup Lagoon, south-western Australia. *Australian Geographer*, 31, 41-54.

Ellis, P. & Williams, W. D. (1970). The biology of Haloniscus searlei Chilton, an oniscid isopod living in Australian salt lakes. *Australian Journal of Marine and Freshwater Research*, 21, 51-69.

Erhard, F. (1998). Phylogenetic relationships within the Oniscidea (Crustacea: Isopoda). *Israel Journal of Zoology* 44, 303-309.

Facelli, J. M. & Pickett, S. T. A. (1991). Plant litter: its dynamic and effects on plant community structure. *The Botanical Review*, 57, 1-32.

Fallaci, M., Colombini I., Taiti S. & Chelazzi, L. (1996). Environmental factors influencing the surface activity and zonation of Tylos europaeus (Crustacea: Oniscidea) on a Tyrrhenian sandy beach. *Marine Biology* (Berlin) 125, 751-763.

Fayos, C. B. (1997). The roles of texture and structure in the water retention capacity of burnt Mediterranean soils with varying rainfall. *Catena*, 31, 219-236.

Garkaklis, M. J., Bradley, J. S. & Wooler, R. D. (1998). The effects of woylie (Bettongia penicillata) foraging on soil water repellency and water infiltration in heavy textured soils in southwestern Australia. *Australian Journal of Ecology*, 23, 492-496.

Gardner, C. A. (1942). The vegetation of western Australia with special reference to climate and soils. *Journal of the Royal Society of Western Australia*, 28, 11-86.

Garnett, S. (1992). *The action plan for Australian Birds*. Canberra: Australian National Parks and Wildlife Service.

Gaston, K. J. (1994). *Rarity*. London: Chapman and Hall

Gentilli. (1979). Regions and Landscapes. Nature and size, function and change. In J. Gentilli (Ed) *Western landscapes* (pp. 3-48). Nedlands: University of Western Australia Press.

Giribet, G. (2003). Karnpurcellia, a new pettalid genus (Arachnida: Opiliones: Cyphophthalmi) from Western Australia, with a cladistic analysis of the family Pettalidae. *Invertebrate Systematics*, 17, 387-406.

Glassford, D. K. & Killigrew, L. P. (1976). Evidence for the westward extension of the Australian desert into south-western Australia. *Search*, 7, 394-396.

Green, A. J. A. (1961). A study of Tasmanian Oniscoidea (Crustacea: Isopoda). *Australian Journal of Zoology*, 9, 258-366.

Green, A. J. A. (1966). Notes on species of Actaecia Dana (Isopoda, Oniscoidea) from Tasmania and New Zealand. *Paper and Proceedings of the Royal Society of Tasmania*, 100, 67-9.

Green, A. J. A. (1971). Styloniscidae (Isopoda, Oniscoidea) from Tasmania and New Zealand. *Papers and proceedings of the Royal Society of Tasmania*, 105, 59-74.

Green, A. J. A. (1974). Oniscidea (Terrestrial Isopoda). In W. D. Williams (Ed.), *Biogeography and ecology in Tasmania* (pp. 229-249). The Hague: W. Junk.

Green, A. J. A. (1990). Selection of type species for two Australian genera of Philosciidae (Isopoda: Oniscidea). *Crustaceana*, 58, 227-228.

Green, A. J. A., Ferrara, F. & Taiti, S. (1990). Terrestrial isopoda from the Krakatau islands, south Sumatra and west Java. *Memoirs of the Museum of Victoria*, 50, 417-436.

Grigg, A. H. & Mulligan, D. R. (1999). Litterfall from two eucalypt woodlands in central Queensland. *Australian Journal of Ecology*, 24, 662-664.

Grove, S. J. (2001). Extent and decomposition of dead wood in Australian lowland tropical rainforest with different management histories. *Forest Ecology and Management*, 154, 35-53.

Growns, I. O. & Davis, J. A. (1991). Comparison of the macroinvertebrate communities in steams in logged and undisturbed catchments 8 years after harvesting. *Australian Journal of Marine and Freshwater Research*, 42, 689-706.

Growns, I. O. & Davis, J. A. (1994). Effects of forestry activities (clearfelling) on stream macroinvertebrate fauna in south-western Australia. *Australian Journal of Marine and Freshwater Research*, 45, 963-975.

Hallam, S. J. (1975). *Fire and hearth: A study of Aboriginal usage and European usurpation in south-western Australia*. Canberra: Australian Institute of Aboriginal Studies.

Hansen, B. & Richardson, A. M. M. (2002). Geographic ranges, sympatry and the influence of environmental factors on the distribution of species of an endemic Tasmanian freshwater crayfish. *Invertebrate Systematics*, 16, 621-629.

Harmon, M. E., Cromak Jr. K. & Smith, B. G. (1987). Coarse woody debris in mixed-conifer forests, Sequoia National Park, California. *Canadian Journal of Forest Research*, 17, 1265-1272.

Harmon, M. E., Franklin, J. F., Swanson, F. J., Sollins, P., Gregory, S. V., Lattin, J. D., et al. (1986). Ecology of coarse woody debris in temperate ecosystems. *Advances in Ecological Research*, 15, 133-302.

Hart, D. D. & Horwitz, R. J. (1991) Habitat diversity and the species-area relationship: Alternative models and tests. In S. S. Bell, E. D. McCoy & H. R. Mushinsky (Eds) *Habitat structure: The physical arrangement of objects in space* (pp. 47-68). London: Chapman and Hall.

Harvey, M. S. (2002). Short-range endemism among the Australian fauna: some examples from non-marine environments. *Invertebrate Systematics*, 16, 555-570.

Harvey, M. S., Dell, J., How, R. & Waldock, J. (1997). *Ground fauna of bushland remnants on the Ridge Hill Shelf end Pinjarra un landforms, Perth.* Unpublished report to the Australian Heritage Commission and the Western Australian Museum and the Western Australian Naturalists Club

Hassall, M., Turner, J. G., & Rands, M. R. W. (1987) . terrestrial isopods on the decomposition of woodland leaf litter. *Oecologia, 72,* ... 4

Hassell, C. W. & Dodson, J. R. (2003). The fire history of south-west Australia prior to European settlement in 1826-1829. In I. Abbott & N. Burrows (Eds.), *Fire in ecosystems of south-western Australia: impacts and management* (pp. 71-86). Leiden: Backhuys Publishers.

Heinzelmann, C. S., Crawford, C. S., Molles, M. C. J., & Warburg, M. R. (1995). Microhabitat selection by Armadillidium vulgare in a riparian forest: Lack of apparent influence by leaf litter food quality. In M. A. Alikhan (Ed.) *Crustacean Issues 9: Terrestrial isopod biology* (pp. 133-143). Rotterdam: A. A. Balkema.

Heberle, G. (1997). Timber harvesting of Crown land in the south-west of Western Australia: an historical review with maps. *CALMScience*, 2, 203-224.

Holdich, D. M., Lincoln, R. J. & Ellis, J. P. (1984). The biology of terrestrial isopods: Terminology and classification. *Symposia of the Zoological Society of London (1984)*, 53, 1-6.

Holland, E. A. & Coleman, D. C. (1987). Litter placement effects on microbial and organic matter dynamics in an agroecosystem. *Ecology*, 68, 425-433.

Hopkin, S. (1991). A key to the woodlice of Britain and Ireland. *Field Studies* 7(4), 599-650. (reprinted by the Field Studies Council, AIDGAP Key, no 204)

Hopkins, A. J. M. & Robinson, C. J. (1981). Fire induced structural change in a Western Australian woodland. *Austrelian Journal of Ecology*, 6, 177-188.

Hopkins, A. J. M., Keighery, G. J. & Marchant, N. G. (1983). Species-rich uplands of south-western Australia. *Proceedings of the Ecological Society of Australia*, 12, 15-26.

Hopper, S. D. (1979). Biogeographical aspects of speciation in the southwest Australian flora. Annual *Review of Ecology and Systematics*, 10, 399-422.

Hopper, S. D. (1992). Patterns of diversity at the population and species levels in south-west Australian Mediterranean ecosystems in Australia. In R. J. Hobbs (Ed.), *Biodiversity in Mediterranean ecosystems* (pp. 27-46). Chipping Norton: Surrey Beatty & Sons.

Hopper, S. D. (2003). An evolutionary perspective on south-west Western Australian landscapes, biodiversity and fire: a review and management implications . In I. Abbott & N. Burrows (Eds.), *Fire in ecosystems of south-western Australia: impacts and management* (pp. 9-35). Leiden: Backhuys Publishers.

Hopper, S. D., Harvey, M. S., Chappill, J. A., Main, A. R. & Main, B. Y. (1996). The Western Australian biota as Gondwanan heritage - a review. In S. D. Hopper, et. al. (Ed.), *Gondwanan Heritage: past, present and future of the Western Australian biota* (pp. 1-46). Chipping Norton: Surrey Beatty & Sons.

Hopper, S. D., Keighery, G. J. & Wardell-Johnson, G. J. (1992). Flora of the karn forest and other communities in the Warren Botanical Subdistrict of Western Australia. In *Research on the impact of forest management in south-west western Australia* (CALM Occasional Paper, No. 2/92, pp. 1-32). Perth: Western Australian Department of Conservation and Land Management.

Hopper, S. J., Harvey, M. S., Chappill, J. A., Main, A. R. & Main, B. Y. (1996). The Western Australian biota as Gondwanan heritage - a review. In S. J. Hopper, J. A. Chappill, M. S. Harvey & A. S. George (Eds.), *Gondwanan heritage past, present and future of the Western Australia biota* (pp. 1-46). Chipping Norton: Surrey Beatty & Sons.

Hornung, E. & Warburg, M. R. (1995). Isopod distribution at different scaling levels. In M. A. Alikhan (Ed.) *Crustacean issues 9: Terrestrial isopod biology* (pp. 83-96) Rotterdam: A. A. Balkema.

Horwitz, P. (1988). Sea level fluctuations and the distributions of some freshwater crayfishes of the genus Engaeus (Decapoda; Parastacidae) in the Bass Strait area. *Australian Journal of Marine and Freshwater Research*, 39, 497-502.

Horwitz, P. (1994). *Patterns of endemism of the freshwater fauna in far southern peatlands and shrublands, Western Australia.* Report prepared for the Australian Heritage Commission and Heritage Council of Western Australia. Environmental Management commissioned report 1994-04. Perth: Edith Cowan University

Horwitz, P. (1997). Comparative endemism and richness of the aquatic fauna in peatlands and shrublands of far south-western Australia. *Memoirs of the Museum of Victoria*, 56, 313-321.

Horwitz, P. & Adams, M. (2000). The systematics, biogeography and conservation status of the species in the freshwater crayfish genus Engaewa Riek (Decapoda:Parastacidae) from south-western Australia. *Invertebrate Taxonomy*, 14, 655-680.

Horwitz, P., Judd, S. & Sommer, B. (2003). Fire and organic substrates: soil structrure, water quality and biodiversity in far south western Australia. In I. Abbott & N. Burrows (Eds.), *Fire in ecosystems of south-western Australia: impacts and management* (pp.381-393). Leiden: Backhuys Publishers

Horwitz, P., Pemberton, M. & Ryder, D (1999). . Catastrophic loss of organic carbon from a management fire in a peatland in south-western Australia. In McComb, A. J. & Davis, J. A. (Eds), *Wetlands for the future* (pp. 487-501). Adelaide: Gleneagles Press.

Horwitz, P., Recher H. & Majer, J. (1999). Putting invertebrates on the agenda: political and bureaucratic challenges. In W. F. Ponder & D. Lunney (Eds.), *The other 99%: The conservation and biodiversity of invertebretes* (pp. 398-406): Mosman: The Royal Zoological Society of New South Wales

How, R., Harvey, M. S., Dell, J. & Waldock, J. (1996). *Ground fauna of urban bushland remnants in Perth.* Unpublished report to the Australian Heritage Commission. Perth: Western Australian Museum.

How, R. A. & Dell, J. (1994). The zoogeographic significance of urban bushland remnants to reptiles in the Perth region. *Pacific Conservation Biology*, 1, 132-140.

Howard, D. M. & Howard, P. J. A. (1980). Effect of species, source of litter, type of soil and climate on litter decomposition. *Oikos*, 34, 115-124.

Howard, T. M. (1974). Litter fauna in Nothofagus cunninghamii forests. *Proceedings of the Royal Society of Victoria*, 1973/4, 207-213.

Howard, T. M. & Ashton, D. H. (1974). The distribution of Nothofagus cunninghamii rainforest. *Proceedings of the Royal Society of Victoria*, 1973/4, 47-58.

Hutson, B. R. & Veitch, L. G. (1985). Relationships between litterfall rate, litter mass and decomposition rate in Eucalyptus forests in southeastern Australia. *Australian Journal of Ecology*, 10, 443-450.

Indian Ocean Climate Initiative Panel (IOCIP) (2002). *Climate variability and change in south-west Western Australia*. Perth: Department of Environment, Water Catchment and Protection.

Incerti, M., Clinnick, P. F. & Willatt, S. T. (1987). Changes in the physical properties of soil following logging. *Australian Forest Research*, 17, 91-98.

Jass, J. & Klausmeier, B. (2000). Endemics and Immigrants: North American terrestrial isopods (Isopoda, Oniscidea) north of Mexico. *Crustaceana*, 73, 771-799.

Jenkins, C. F. H. (1982). Notes on the biogeographical regions of Australia. *Journal of the Royal Society of Western Australia*, 65, 115-18.

Johnson, M. P., Frost, N. J., Mosley, M. W. J., Roberts, M. F., & Hawkins, S. J. (2003). The area-independent effects of habitat complexity on biodiversity vary between regions. *Ecology Letters*, 6, 126-132.

Jones, D. S. (1986). A catalogue of type specimens of Crustacea in the Western Australian Museum, Perth. *Records of the Western Australian Museum*, 13, 1-46.

Judd, S. (1994). *Mainland, rare and threatened vertebrates of the Darling Botanical District, Western Australia. A status report with recommendations in respect to applicable Commonwealth legislation, agreements and policy*. Unpublished report for Christabel Chamarette, Senator for Western Australia (The Greens WA)

Judd, S., Horwitz, P. & Jones, D. S. (1999). Distribution patterns of inland aquatic and terrestrial malacostracan crustaceans in south-western Australia. In *Dampier 300: Biodiversity in Australia, Program and Abstracts* (pp. 54-55). Perth: Australian Systematic Botany Society and Society of Australian Systematic Biologists.

Judd, S. & Horwitz, P. (2003). Diversity and biogeography of terrestrial isopods (Crustacea: Oniscidea) from south-western Australia: Organic matter and matter and microhabitat utilisation in seasonally dry landscapes. *Crustaceana Monographs*, 2, 191-215.

Keast, A. (1981). Distributional patterns, regional biotas, and adaptations in the Australian biota: a synthesis. In A. Keast (Ed.), *Ecological biogeography of Australia* (pp. 1891-1997). The Hague: Dr. W. Junk Publishers.

Kendrick, G. W. (1977). Middle Holocene marine molluscs from near Guildford, Western Australia and evidence for climatic change. *Journal of the Royal Society of Western Australia*, 59, 97-104.

Kendrick, G. W., Wyroll, K. H. & Szabot, B. J. (1991). Pliocene and Pleistocene coastal events and history along the western margin of Australia. *Quaternary Science Review*, 10, 419-439.

Kershaw, A. P. & Nanson, G. C. (1993). The last full glacial cycle in the Australian region. *Global and Planetary Change*, 7, 1-9.

Kautz, G., Zimmer, M., & Topp, W. (2000). Responses of the parthenogenetic isopod, Trichoniscus pusillus (Isopoda: Oniscidea) to changes in food quality. *Pedobiologia*, 44, 77-85.

Koch, L. E. & Majer, J. D. (1980). A phenological investigation of various invertebrates in forest and woodland areas in the south-west of Western Australia. *Journal of the Royal Society of Western Australia*, 63, 21-28.

Koleff, P. & Gaston, K. J. (2002). The relationships between local and regional species richness and spatial turnover. *Global Ecology and Biogeography*, 11, 363-375.

Kwon, D. H., Ferrara, F. & Taiti, S. (1992). Two new species of Laureola Barnard, 1960 form India and Vietnam (Crustacea, Oniscidea, Armadillidae). *Revue Suisse de Zoologie*, 99, 645-653.

Laurence, W. F. & Yensen, E. (1991). Predicting the impact of edge effects in fragmented habitats. *Biological Conservation*, 55, 77-92.

Lee, K. E. & Correll, R. L. (1978). Litter fall and its relationship to nutrient cycling in a south Australian dry sclerophyll forest. *Australian Journal of Ecology*, 3, 243-252.

Lehtinen, P. T., Taiti, S. & Ferrara, F. (1998). Case 2911. Spherillo Dana, 1852 (Crustacea, Isopoda): proposed designation of S. vitiensis Dana, 1853 as the type species, with designation of a neotype. *Bulletin of Zoological Nomenclature*, 55, 217-219.

Liechty, H. O., Holmes, M. J., Reed, D. D. & Mroz, G. D. (1992). Changes in microclimate after stand conversion in two northern hardwood stands. *Forest Ecology and Management*, 50, 253-264.

Leirós, M. C., Trasar-Cepeda, C., Seoane, S. & Gil-Sotres, F. (1999). Dependence of mineralization of soil organic matter on the temperature and moisture. *Soil Biology & Biochemistry*, 31, 327-335.

Lemos de Castro, A. (1972). Consideracoes sobre o genero Reductoniscus, com descricao de uma especie nova (Isopoda, Oniscoidea). *Revista Brasileira de Biologia* 32, 347-349.

Lewis, F. (1990). Tylos bilobus sp. nov., a second Australian species of Tylidae (Crustacea: Isopoda: Oniscidea). *Memoirs of the Museum of Victoria*, 51, 93-97.

Lewis, F. (1991). A new species of Tylos Audouin (Isopoda: Oniscidea: Tylidae) from Western Australia. *Records of the Western Australian Museum*, 15, 109-116.

Lewis, F. (1998a). Oniscidea (Isopoda) from Lord Howe Island. *Crustaceana*, 71, 743-777.

Lewis, F. (1998b). New genera and species of terrestrial Isopods (Crustacea: Oniscidea) from Australia. *Journal of Natural History*, 32, 701-732.

Lewis, F. & Bishop, L. (1990). Tylos australis: a new species of Tylidae (Isopoda: Oniscidea), a family previously not recorded in Australia. *Invertebrate Taxonomy*, 3, 747-757.

Lewis, F. & Green, A. J. A. (1994). Four new species of Actaeciidae (Isopoda: Oniscidea:) from Australia, with a review of the family. *Invertebrate Taxonomy*, 8, 1421-1442.

Lillemets, B. & Wilson, G. D. F. (2002). Armadillidae (Crustacea: Isopoda) from Lord Howe Island: New taxa and biogeography. *Records of the Australian Museum*, 54, 71-98

Lindenmayer, D. B., Incoll, R. D., Cunningham, R. B. & Donnelly, C. F. (1999). Attributes of logs on the floor of mountain ash (Eucalyptus regnans) forests of different ages *Forest Ecology and Management*, 123, 195-203.

Lindenmayer, D. B., Claridge, A. W., Gilmore, A. M., Michael, D. & Lindenmayer, B. D. (2002). The ecological roles of logs in Australian forests and the potential impacts of harvesting intensification on log-using biota. *Pacific Conservation Biology*, 8, 121-140

Littlejohn, M. J. (1981). The amphibia of mesic southern Australia. In A. Keast (Ed.), *Ecological biogeography of Australia* (pp. 1303-1330). The Hague: Dr W Junk.

Lomolino, M. V. (2001). The species-area relationship: new challenges for an old pattern. *Progress in Physical Geography*, 25, 1-21.

Lomolino, M. V. & Channell, R. (1995). Splendid isolation: patterns of geographic range collapse in endangered mammals. *Journal of Mammalogy*, 76, 335-347.

Ma, H. H. T., Dudgeon, D. & Lam, P. K. S. (1991). Seasonal changes in population of three sympatric isopods in a Hong Kong forest. *Journal of Zoology, London*, 224, 347-365.

MacNally, R., Parkinson, A., Horrocks, G., Conole, L. & Tzaros, C. (2001). Relationships between terrestrial vertebrate diversity, abundance and availability of coarse woody debris on south-eastern Australian floodplains. *Biological Conservation*, 99, 191-205.

Main A. R. & Main B. Y. (1996). *Report on the Southern Forest Region of Western Australia*. Unpublished report to the Australian Heritage Commission.

Main, B. Y. (1991). Occurrence of the trapdoor spider genus Moggridgea in Australia with descriptions of two new species (Araneae: Mygalomorphae: Migidae). *Journal of Natural History*, 25, 383-397.

Main, B. Y. (1996a). Terrestrial invertebrates in south-west Australian forests: the role of relict species and habitats in reserve design. *Journal of the Royal Society of Western Australia*, 79, 277-280.

Main, B. Y. (1996b). Microcosmic biogeography: trapdoor spiders in a time warp. In S. J. Hopper, J. A. Chappill, M. S. Harvey & B. Y. Main (Eds.), *Gondwanan heritage past, present and future of the Western Australian biota* (pp. 163-171). Chipping Norton: Surrey Beatty & Sons.

Main, B. Y. (1999). Biological anachronisms among trapdoor spiders reflect Australia's environmental changes since the Mesozoic. In W. F. Ponder & D. Lunney (Eds.), *The other 99%: The conservation and biodiversity of invertebrates* (pp. 236-45): Mosman: The Royal Zoological Society of New South Wales.

Main, B. Y. (2000). Habitat template for invertebrates on granite outcrops. *Journal of the Royal Society of Western Australia*, 83, 139-147.

Majer, J. D. (1984). Short-term responses of soil and litter invertebrates to a cool autumn burn in Jarrah (Eucalyptus marginata) forest in Western Australia. *Pedobiologia*, 26, 229-247.

Majer, J. D. (1985). Fire effects on invertebrate fauna of forest and woodland. In J. R. Ford. (Ed.), *Fire ecology and management in Western Australian ecosystems. Proceedings of a symposium held in Perth on 10-11 May 1985* (pp. 103-106). Perth: Western Australian Institute of Technology.

Majer, J. D. (1997). The use of pitfall traps for sampling ants – a critique. *Memoirs of the Museum of Victoria*, 56, 323-329.

Majer, J. D. & Abbott, I. (1989). Invertebrates of the jarrah forest. In B. Dell (Ed.), *The jarrah forest. A complex Mediterranean ecosystem* (pp. 111-122). Dordrecht: Kluwer Academic Publishers.

Majer, J. D. & Chia. (1980). *An inventory of information on terrestrial invertebrates occurring in Western Australia*. Western Australian Institute of Technology, Biology Department Bulletin, No 1.

Majer, J. D. & Heterick, B. E. (1997). *Report on the impact of disturbance on terrestrial invertebrates in the Western Australian RFA area for the Commonwealth and Western Australian Governments*. Perth: Curtin University.

Majer, J. D. & Koch, L. E. (1982). Seasonal activity of hexapods in woodland and forest leaf litter in the south-west of Western Australia. *Journal of the Royal Society of Western Australia*, 65, 37-45.

Mallik, A. U., Gimingham, C. H. & Rahman, A. A. (1984). Ecological effects of heather burning I: water infiltration, moisture retention and porosity of surface soil. *Journal of Ecology*, 72, 767-776.

Marra, J. L. & Edmonds, R. L. (1998). Effects of coarse woody debris and soil depth on the density and diversity of soil invertebrates on clearcut and forested sites on the Olympic Peninsula, Washington. *Environmental Entomology*, 27, 1111-1124.

Marchant, N. G. (1973). Species diversity in the southwestern flora. *Journal of the Royal Society of Western Australia*, 56, 23-30.

Ma, H. H. T., Dudgeon, D. & Lam, P. K. S. (1991). Seasonal changes in populations of three sympatric isopods in a Hong Kong forest. *Journal of Zoology, London*, 224, 347-365.

Ma'Shum, M., Tate, M. E., Jones, G. P. & Oades, J. M. (1988). Extraction and characterisation of water repellent materials from Australian soils. *Journal of Soil Science*, 39, 99-110.

Matlack, G. (1993). Microenvironment variation within and among forest edge sites in the eastern United States. *Biological Conservation*, 66, 185-194.

Mattiske, E. M. & Havel, J. J. (1998). *Vegetation mapping in the south west of Western Australia*. Perth: Western Australian Department of Conservation and Land Management.

McCaw, W. L., Neal, J. E. & Smith, R. H. (1996). Effects of fuel reduction burning on fire behaviour and suppression difficulty of an intense wildfire in jarrah (Eucalyptus marginata) forest – a case study. *CALMScience*, 2, 141-148.

McCaw, W. L., Neal, J. E. & Smith, R. H. (2002). Stand characteristics and fuel accumulation in a sequence of even-aged karri (Eucalyptus diversicolor) stands in south-west Australia. *Forest Ecology and Management*, 158, 263-271.

McIvor, J. G. (2001). Litterfall from trees in semiarid woodlands of north-east Queensland. *Austral Ecology*, 26, 150-155.

McKissock, I., Gilkes, R. J. & van Bronswijk, W. (2003). The relationship of sopil water repellency to aliphatic C and kaolin measured using DRIFT. *Australian Journal of Soil Research*, 41, 251-265.

McKissock, I., Gilkes, R. J., Harper, R. J. & Carter, D. J. (1998). Relationships of water repellency to soil properties for different spatial scales of study. *Australian Journal of Soil Research*, 36, 495-508.

Michaelsen, W. & R. Hartmeyer (1905). *Die fauna Sudwest-Australiens*. Jena: Fischer

Melbourne, B. A. (1999). Bias in the effect of habitat structure on pitfall traps: An experimental evaluation. *Australian Journal of Ecology*, 24, 228-239.

Mesibov, R. (1994). Faunal breaks in Tasmania and their significance for invertebrate conservation. *Memoirs of the Queensland Museum*, 36, 133-136.

Mesibov, R. (1999). The Mersey Break: an unexplained faunal boundary on the north coast of Tasmania. In W. F. Ponder & D. Lunney (Eds.), *The other 99%: The conservation and biodiversity of invertebrates* (pp. 246-52). Mosman: The Royal Zoological Society of New South Wales.

Moore, J. A. (1961). The frogs of eastern New South Wales. *Bulletin of the American Museum of Natural History*, 121, 149-386.

Morgan, D., Gill, H. & Potter, I. (1996). *The distribution of freshwater fishes in the south-western corner of Australia* (Water Resource Technical Series No. WRT4). Perth: Water and Rivers Commission.

Morrissy, N. M. (1978). The past and present distribution of marron, Cherax tenuimanus (Smith), in Western Australia. *Fisheries Research Bulletin Western Australia*, 22, 1-38.

Mulcahy, M. J. (1967). Landscapes, laterites and soils in southwestern Australia. In J. N. Jennings & J. A. Mabbutt (Eds.), *Landform studies from Australia and New Guinea* (pp. 211-230). London: Cambridge University Press.

Mulcahy, M. J. (1973). Landforms and soils of Western Australia. *Journal of the Royal Society of Western Australia*, 56, 16-22.

Myers, A. A. & Giller, P. S. (Eds.) (1988). *Analytical biogeography. An integrated approach to the study of animal and plant distributions*. London: Chapman and Hall.

Myers, N., Mittermeier, R. A., Mittermeier, C. G., da Fonseca, G. A. B. & Kent, J. (2000). Biodiversity hotspots for conservation priorities. *Nature*, 403, 853-857.

Nair, G. A. & Aljetlawi, A. A. (1993). Observations on the relation of body dimensions and the ecological factors of the soil influencing the abundance of the pillbug, Armadillo officinalis Dumerill, 1816 (Isopoda: Oniscidea) in Benghazi, Libya. *Journal of Animal Morphology and Physiology* 40, 61-71.

Nair, G. A., Fadiel, M. M. & Mohamed, A. I. (1989). Effects of temperature on transpiration behaviour growth and feeding habits of Armadillo officinalis (Isopoda, Oniscidea) in Benghazi, Libya. *Journal of Arid Environments*, 17, 49-55.

National Land and Water Resources Audit (NLWRA) (2002). *Australian terrestrial biodiversity assessment*. Canberra: National Land and Water Resource Audit.

Neumann, F. G. (1991). Responses of litter arthropods to major or artificial ecological disturbances in mountain ash forests. *Australian Journal of Ecology*, 16, 19-32.

Neumann, F. G., & Tolhurst, K. (1991). Effects of fuel reduction burning on epigeal arthropods and earthworms in dry sclerophyll eucalypt forest of west-central Victoria. *Australian Journal of Ecology*, 16, 315-330.

Newsome, D. (2000). Origin of sandplains in Western Australia: a review of the debate and some recent findings. *Australian Journal of Earth Sciences*, 47, 695-706.

Nicholls, G. E. (1933). The composition and biogeographical relations of the fauna of Western Australia. *Report of the Australasian Association for the Advancement of Science*, 21, 93-138.

Nicholls, G. E. & Barnes, H. M. (1926a). Description of a new species of terrestrial isopod, Haloniscus stepheni, from Western Australia. *Journal of the Royal Society of Western Australia*, 12, 87-97.

Nicholls, G. E. & Barnes, H. M. (1926b). A description of two new terrestrial isopods from Western Australia. *Journal of the Royal Society of Western Australia*, 22, 149-159.

O'Connell, A. M. (1986). Effect of legume understorey on decomposition and nutrient content of eucalypt forest litter. *Plant and Soil*, 92, 235-248.

O'Connell, A. M. (1987). Litter decomposition, soil respiration and soil chemical and biochemical properties at three contrasting sites in karri (Eucalyptus diversicolor F. Muell.) forests of south-western Australia. *Australian Journal of Ecology*, 12, 31-40.

O'Connell, A. M. (1988). Decomposition of leaf litter in karri (Eucalyptus diversicolor) forest of varying age. *Forest Ecology and Management*, 24, 113-125.

O'Connell, A. M., Grove, T. S. & Dimmock, G. M. (1978). Nutrients in the litter on jarrah forest soils. *Australian Journal of Ecology*, 3, 253-260.

O'Connell, A. M., Grove, T. S. & Dimmock, G. M. (1979). The effects of high intensity fire on nutrient cycling in jarrah forest. *Australian Journal of Ecology*, 4, 331-337.

O'Connell, A. M. & Menage, P. (1983?). Decomposition of litter from three major plant species of jarrah (Eucalyptus marginata) forest in relation to site fire history and soil type. *Australian Journal of Ecology*, 8, 277-286.

Olson, D. M., Dinerstein, E., Powell, G. V. N. & Wikramanayake, E. D. (2002). Conservation biology for the biodiversity crisis. *Conservation Biology*, 16, 1-3.

Paoletti, M.G. & Hassall, M. (1999). Woodlice (Isopoda: Oniscidea): their potential for assessing sustainability and use as bioindicators. *Agriculture, Ecosystems and Environment*, 74: 157-165.

Paterson, H. E. & James, S. H. (1973). Animal and plant speciation studies in Western Australia. *Journal of the Royal Society of Western Australia*, 56, 31-43.

Pearson, D. L. & Carroll, S. S. (1996). Global patterns of species richness: Spatial models for conservation planning using bioindicator and precipitation data. *Conservation Biology*, 12, 809-821

Perez, F. L. (1998). Conservation of soil moisture by different stone covers on alpine talus slopes (Lassen, California). *Catena*, 33, 155-177.

Piearce, T. G. (1989). Acceptability of pteridophyte litters to Lumbricus terrestris and Oniscus asellus and the implication for the nature of ancient soils. *Pedobiologia*, 33, 91-100.

Plaster, E. J. (1992). *Soil Science and Management* (2nd Edition). New York: Delmar Publishers Inc.

Ponder, W. F., Clark, S. A. & Miller, A. C. (1999). A new genus and two new species of Hydrobiidae (Mollusca: Gastropoda: Caenogastropoda) from south Western Australia. *Journal of the Royal Society of Western Australia*, 82, 109-120.

Ponder, W. F. & Colgan. D. J. (2002). What makes a narrow-range taxon? Insights from Australian freshwater snails. *Invertebrate Systematics*, 16, 571-582.

Prendergast, J. R., Quinn, R. M., Lawton, J. H., Eversham, B. C. & Gibbons, D. W. (1993). Rare species, the coincidence of diversity hotspots and conservation strategies. *Nature*, 365, 335-337.

Proctor, H. C., Montgomery, K. M., Rosen, K. E. & Kitching, R. L. (2002). Are tree trunks habitats or highways? A comparison of oribatid mite assemblages from hoop-pine bark and litter. *Australian Journal of Entomology*, 41, 294-299.

Pyle, C. & Brown, M. M. (1999). Heterogeneity of wood decay class within hardwood logs. *Forest Ecology and Management*, 114, 253-259.

Rayment, G. E. & Higginson, (1992). *Australian laboratory handbook of soil and water chemical methods*. Melbourne : Inkata Press.

Roberts, J. D., Horwitz, P., Wardell-Johnson, G., Maxson, L. R. & Mahoney, M. J. (1997). Taxonomy, relationships and conservation of a new genus and species of Myobatrachid frog from the high rainfall region of southwestern Australia. *Copeia*, 1997, 373-381.

Rosenzweig, M. L. (1995). *Species diversity in space and time*. New York: Cambridge University Press.

Ross, K. A., Fox, B. J. & Fox, M. D. (2002). Changes to plant species richness in forest fragments: fragment age, disturbance and fire history may be as important as area. *Journal of Biogeography*, 29, 749-765.

Rossbach, M. H. & Majer, J. D. (1983). A preliminary survey of the ant fauna of the Darling Plateau and Swan Coastal Plain near Perth, Western Australia. *Journal of the Royal Society of Western Australia*, 66, 85-90.

Rowell, D. (1994). *Soil science : methods and applications*. Harlow, Essex: Addison Wesley Longman.

Rundle, G. E. (1996). History of conservation reserves in the south-west of Western Australia. *Journal of the Royal Society of Western Australia*, 79, 225-240.

Rushton, S. P. (1983). The effects of food quality on the life history parameters of the terrestrial isopod (Armadillidium vulgare (Latrielle). *Oecologia*, 57, 257-261.

Ryder, D. S. (2000). *Origin and fate of organic matter in a south-western Australian Wetlands*. Unpublished PhD Thesis, Edith Cowan University, Perth, Western Australia.

Schmalfaus, H. (1989). Phylogenetics in Oniscidea. *Monitore Zoologico Italiano*, Monogr., 4, 3-27.

Schmalfuss, H. (1984). Eco-morphological strategies in terrestrial isopods. *Symposia of the Zoological Society of London (1984)*, 53, 49-63.

Schmalfuss, H. & Ferrara, F. (1983). Terrestrial isopods from West Africa. Part 3. Family Armadillidae. *Monitore Zoologico Italiano*, 3, 111-157.

Schmidt, C. (2002a). Contribution to the phylogenetic system of the Crinocheta (Crustacea, Isopoda). Part 1 (Olibrinidae to Scyphacidae s. str.). *Mitteilungen aus dem Museum fur Naturkunde in Berlin*, 78, 275-352.

Schmidt, C. (2002b). Contribution to the phylogenetic system of the Crinocheta (Crustacea, Isopoda). Part 2 (Oniscoidea to Armadillidiidae). *Mitteilungen aus dem Museum fur Naturkunde in Berlin*, 79, 3-19.

Seddon, G. (1972). *Sense of Place* (Chapter 1, pp. 3-19). Perth: University of Western Australia Press.

Semenuik, V. (1995). The Holocene record of climatic, eustatic and tectonic events along the coastal zone of Western Australia - A review. *Journal of Coastal Research Special Issue* (17), 2247-2259.

Serventy, D. L. & Whittell, H. M. (1951). *Birds of Western Australia* (Second Edition). Perth: Paterson Press

Sfenthourakis, S. (1996a). A biogeographical analysis of terrestrial isopods (Isopoda, Oniscidea) from the central Aegean islands (Greece). *Journal of Biogeography*, 23, 687-698.

Sfenthourakis, S. (1996b). The species-area relationship of terrestrial isopods (Isopoda; Oniscidea) from the Aegean archipelago (Greece): a comparative study. *Global Ecology and Biogeography Letters*, 5, 149-157.

Singh, G., Kershaw, A. P. & Clark, R. (1981). Quaternary vegetation and fire history in Autralia. In A. M. Gill, R. H. Groves & I. R. Noble (Eds.), *Fire and the Australian biota* (pp. 23-54). Canberra: Australian Academy of Science.

Solem, A., Giradi, E-L., Slack-Smith, S., & Kendrick, G. W. (1982). *Austroassiminea letha* gen. nov., sp. nov., a rare and endangered prosobranch snail from southwestern Australia (Mollusca: Prosobranchia: Assimineidae). *Journal of the Royal Society of Western Australia*, 65, 119-129.

Spain, A. V. (1984). Litterfall and the standing crop of litter in three tropical Australian rainforests. *Journal of Ecology*, 72, 947-961.

Spector, S. (2002). Biogeographic crossroads as priority areas for biodiversity conservation. *Conservation Biology*, 16, 1480-1487.

Spencer, B. (1896). Summary of the zoological results. In *Report of the Horn Expedition to centrel Australia*. Volume 1.

Springett, J. A. (1976). The effect of prescribed burning on the soil fauna and on litter decomposition in Western Australian forests. *Australian Journal of Ecology*, 1, 77-82.

Springett, J. A. (1979). The effects of a single hot summer fire on soil fauna and on litter decomposition in jarrah (Eucalyptus marginata) forest in Western Australia. *Australian Journal of Ecology*, 4, 279-291.

Storey, A. W., Bunn, S. E., Davies, P. M. & Edward, D. H. (1990). Classification of the macroinvertebrate fauna of the river systems in south-western Australia in relation to physical and chemical parameters. *Regulated Rivers: Research and Management*, 5, 217-232.

Storey, A. W., Halse, S. A. & Sheil, R. J. (1993). Aquatic invertebrate fauna of the Two Peoples Bay Area. *Journal of the Royal Society of Western Australia*, 76, 25-32.

Storr, G. M. (1991). Birds of the south-west division of Western Australia. *Records of the Western Australian Museum Supplement No 35*. Perth: Western Australian Museum.

Sutton, S. L. (1972). *Woodlice*. London: Ginn (Republished 1980, Pergamon Press, Oxford

Taiti, S. & Ferrara, F. (1979). Il genere Pseudodiploexochus Arcangeli, 1934. *Revue de Zoologie Africaine*, 101, 69-102.

Taiti, S. & Ferrara, F. (1979). Contributions to the knowledge of the mountain fauna of Malawi. 6. Terrestrial Isopods. *Revue de Zoologie Africaine*, 93, 152-184.

Taiti, S., Ferrara, F. & Iliffe, T. M. (1995). A new species of Haloniscus Chilton, 1920 from New Caledonia (Isopoda, Oniscidea). *Crustaceana*, 68, 321-328.

Taiti, S. & Humphreys, W. F. (2001). New aquatic Oniscidea (Crustacea: Isopoda) from groundwater calcretes of Western Australia. *Records of the Western Australian Museum Supplement*, 64, 133-151.

Taiti, S., Paoli, P. & Ferrara, F. (1998). Morphology, biogeography and ecology of the family Armadillidae (Crustacea: Oniscidea). *Israel Journal of Ecology*, 44, 291-301.

Tajovský, K. (1998). Diversity of terrestrial isopods (Oniscidea) in flooded and non-flooded ecosystems of southern Moravia, Czech Republic. *Israel Journal of Ecology*, 44, 311-322.

Tate, R. (1887). On the influence of physiographic changes in the distribution of life in Australia. *Report of the Australasian Association for the Advancement of Science*, 1, 312-325.

Thackway, R. & Cresswell, I. D. (1995). *An interim biogeographic regionalisation for Australia: a framework for establishing the national system of reserves*, Version 4.0. Canberra: Australian Nature Conservation Agency.

Trayler, K. M., Davis, J. A., Horwitz, P. & Morgan, D. (1996). Aquatic fauna of the Warren Bioregion, south-west Western Australia: Does reservation guarantee preservation? *Journal of the Royal Society of Western Australia*, 79, 281-291.

Triantis, K. A., Mylonas, M., Lika, K. & Vardinoyannis K. (2003) A model for the species-area-habitat relationship. *Journal of Biogeography, 30*, 19-27.

Turnbull, C. R. A. & Madden, J. L. (1983). Relationship of litterfall to basal area and climatic variables in cool temperate forests of southern Tasmania. *Australian Journal of Ecology*, 8, 425-431.

Turner, J. & Lambert, M. J. (2002). Litterfall and forest floor dynamics in Eucalyptus pilularis forests. *Austral Ecology*, 27, 192-199.

Vandel, A. (1955). Les Trichoniscides (Crustacés- Isopodes) de L'Hémispheres Austral leur place systématique leur intéret biogéographique. *Mémoirs du Museum National D'Histoire Naturelle, Nouvelle Série, Série A, Zoologie*, Tome VI(1), 1-116. (Paris: Éditions du Muséum).

Vandel, A. (1973a). Les Isopods terrestres de l'Australie étude systématique et biogéographique. *Mémoirs du Museum National D'Histoire Naturelle, Nouvelle Série, Série A, Zoologie*, Tome LXXXII (Paris: Éditions du Muséum).

Vandel, A. (1973b). Isopodes terrestres de Nepal (Oniscoidea). *Senckenbergiana Biologica*, 54, 111-128.

Verhoeff, K. (1926). Isopoda terrestria von Neu-Caledonia und den Loyalty Inseln. In F. Sarasin & Roux, J. (Eds.) *Nova Caledonia. Zoologie*, 4, 243-366

Voigt, G. K. (1960). Distribution of rainfall under forest stands. *Forest Science*, 6, 2-10.

Wägele, J. W. (1989). Evolution and phylogenetic system der Isopoda. *Zoologica*, 47, 1-262.

Wahrberg, R. (1922). Terrestre Isopoden aus Australien. Results of Dr. E. Mjoberg's swedish scientific expeditions to Australia, 1910-1913. No. 30. *Arkiv for Zoologi*, 15, 1-298.

Waide, R. B, Willig, M. R., Steiner, C. F., Mittelbach, G., Gough, L., Dodson, S. I. Juday, G. P. & Parmenter, R. (1999). The relationship between productivity and species richness. *Annual Review of Ecology and Systematics*, 30, 257-300.

Wallace, W. R. & Hatch, A. B. (1952). The effect of leaf litter on surface soil properties of the jarrah forest. *Australian Forestry*, 16, 35-43.

Warburg, M. R. (1965). The evaporative water loss of three isopods from semi-arid habitats in South Australia. *Crustaceana*, 9, 302-308.

Warburg, M. R. (1993a). *Evolutionary biology of land isopods*. New York: Springer-Verlag.

Warburg, M. R. (1993b). Distribution patterns of isopod species in different habitats. In *Evolutionary biology of land isopods* (pp. 70-84). New York: Springer-Verlag.

Warburg, M. R., Linsenmair, K. E. & Bercovitz, K. (1984). The effect of climate on the distribution and abundance of isopods. *Symposia of the Zoological Society of London*, 53, 339-367.

Ward, D. J., Lamont, B. B., & Burrows, C. L. (2001). Grasstrees reveal contrasting fire regimes in eucalypt forest before and after European settlement of southwestern Australia. *Forest Ecology and Management*, 150, 323-329.

Ward, S. C., Majer, J. D. & O'Connell, A. M. (1991). Decomposition of eucalypt litter on rehabilitated bauxite mines. *Australian Journal of Ecology*, 5, 251-257.

Wardell-Johnson, G. W. & Coates, D. (1996). Links to the past: local endemism in four species of forest eucalypts in southwestern Australia. In S. J. Hopper, J. A. Chappill, M. S. Harvey & B. Y. Main (Eds.), *Gondwanan heritage past, present and future of the Western Australian biota* (pp. 137-154). Chipping Norton: Surrey Beatty & Sons.

Wardell-Johnson, G. & Horwitz, P. (1996). Conserving biodiversity and the recognition of heterogeneity in ancient landscapes: a case study from south-western Australia. *Forest Ecology and Management*, 85, 219-238.

Wardell-Johnson, G. & Horwitz, P. (2000). The recognition of heterogeneity and restricted endemism in the management of forested ecosystems in south-western Australia. *Australian Forestry*, 63, 218-225.

Wardell-Johnson, G. & Nichols, O. (1991). Forest wildlife and habitat management in southwestern Australia: knowledge research and direction. In D. Lunney (Ed.), *Conservation of Australia's forest fauna* (pp. 161-192). Mosman: Royal Zoological Society of New South Wales.

Wardell-Johnson, G. & Roberts, J. D. (1996). Morphological variation in the Geocrinia (Anura: Myobatrachidae) complex in southwestern Australia. In S. J. Hopper, J. A. Chappill, M. S. Harvey & B. Y. Main (Eds.), *Gondwanan heritage past, present and future of the Western Australian biota* (pp. 172-178). Chipping Norton: Surrey Beatty & Sons.

Wardell-Johnson, G. & Williams, M. (1996). A floristic survey of the Tingle Mosaic, south-western Australia: applications in land use planning and management. *Journal of the Royal Society of Western Australia*, 79, 249-276.

Watson A. W. (in prep.). *The importance of logged forest to biodiversity conservation: a case study from the northern Jarrah forest, Western Australia*. Unpublished PhD Thesis, Edith Cowan University, Perth, Western Australia.

Webb, W. M. & Sillem, C. (1906). *The British woodlice*. London: Duckworth.

Whiting, A. S., Lawler, S. H., Horwitz, P. & Crandall, K. A. (2000). Biogeographic regionalisation of Australia: assigning conservation priorities based on endemic freshwater crayfish phylogenetics. *Animal Conservation*, 3, 155-163.

Whittaker, R. H (1977). Evolution of species diversity in land communities. In M. K. Hecht, W. C. Steere & B. Wallace (Eds.) *Evolutionary Biology, Volume 10* (pp. 250-268). New York: Plenum Press.

Whittaker, R. J. (1998). *Island biogeography. Ecology, evolution and conservation*. Oxford: Oxford University Press

Whittaker, R. J., Willis, K. J. & Field, R. (2001). Scale and species richness: toward a general hierarchical theory of species diversity. *Journal of Biogeography*, 28, 453-470.

Williams, W. D. (1970). Redescription of Haloniscus searlei Chilton. 1920 (Isopoda, Oniscoidea, Oniscidae) from an Australian salt lake. *Crustaceana*, 19, 311-319.

Williams, W. D. & Barnard. (1988). The taxonomy of the Crangonyctoid Amphipoda (Crustacea) from Australian fresh waters: Foundation studies. *Records of the Australian Museum*, Supplement 10, 1-180.

Wilson, G. D. F. & Johnson, R. T. (1999). Ancient endemism among freshwater isopods (Crustacea, Phreatoicidea). In W. F. Ponder & D. Lunney (Eds.), *The other 99%: The conservation and biodiversity of invertebrates* (pp. 264-68). Mosman: The Royal Zoological Society of New South Wales.

Wilson, G. D. F. & Keable, S. J. (2002). New genera of Phreatoicidea (Crustacea: Isopoda) from Western Australia. *Records of the Australian Museum*, 54, 41-70.

Woods, P. V. & Raison, R. J. (1983). Decomposition of litter in sub-alpine forests of Eucalyptus delegatensis, E. pauciflora and E. dives. *Australian Journal of Ecology*, 8, 287-299.

Wright, B. (1992). Getting drier in the West. *Ecos*, 72, 6-10.

Wright, J. C. & Machin, J. (1990). Water vapour absorption in terrestrial isopods. *Journal of Experimental Biology*, 154, 13-30.

Wright, J. C. & Machin, J. (1993). Atmospheric water absorption and the water budget of terrestrial isopods Crustacea Isopoda Oniscidea. *Biological Bulletin*, 184, 243-253.

Wronski, E. B. (1984). Impact of tractor thinning operations on soils and tree roots in a karri forest, Western Australia. *Australian Forestry Research*, 14, 319-332.

Wyroll, K. H. (1979). Late Quaternary climates of Western Australia: evidence and mechanisms. *Journal of the Royal Society of Western Australia*, 62, 129-142.

Zar, J. H. (1984). *Biostatistical analysis* (Second Edition). New Jersey: Prentice-Hall International.

Ziegler, S. S. (2000). A comparison of structural characteristics between old-growth and postfire second-growth hemlock-hardwood forests in Adirondack Park, New York, U.S.A. *Global Ecology & Biogeography*, 9, 373-389.

Zimmer, M. (2002). Nutrition in terrestrial isopods (Isopoda: Oniscidea): an evolutionary-ecological approach. *Biological Review*, 77, 455-493.

Zimmer, M. (2003). Habitat and resource use by terrestrial isopods. *Crustacea Monographs*, 2, 243-262.

Zimmer, M., & Topp, W. (1997). Does leaf litter quality influence population parameters of the common woodlouse, Porcellio scaber (Crustacea: Isopoda)? *Biology and. Fertility of Soils*, 24, 435-441.

APPENDIX 1.

SITE DESCRIPTIONS

Appendix 1a.

List of site names, localities, land tenure and site notes. Sites where litter samples were taken for extraction by Berlese funnels (BF) are indicated. Latitude and longitude coordinates are in decimals. Refer to the text Section 2.4.2 for an explanation of the site descriptions, slope and aspect. Descriptions of the vegetation associations (Veg) are given in Appendix 1b.

Site	Name	Date	Locality	BF	Tenure	Veg	Site Description	Slope	Aspect	Latitude	Longitude
1	Dunsborough (Commonage/Wildwood Rds) *	15-Jul-98	57 Yallingup		PP	3	Long unburnt remnant jarrah and marri forest with banksias and grass trees.	0		-33.6920	115.0670
2.	Cape Clairault *	15-Jul-98	57 Yallingup	Y	NP	1180	Coastal limestone headland with sparse coastal scrub.	5	N	-33.6930	114.9750
3	Jimperding Brook *	20-Jul-98	20 Toodyay	Y	RR	4	Riparian zone with flooded gums.	0		-31.6210	116.4170
4	Ridley Rd (Mt. Billy)	22-Jul-98	23 Chidlow		SF	4	Wandoo woodland with grasstrees.	0		-31.9420	116.4330
5	Ridley Rd (Mt. Yetar)	22-Jul-98	23 Chidlow		SF	4	Open wandoo woodland with laterite outcropping and banksias sloping down to creek.	3/4	N	-31.9420	116.4000
6	Leona Rd	23-Jul-98	27 Beraking		SF	3	Jarrah and marri forest with banksias and grass trees.	1	SW	-32.2180	116.3250
7	Booma Rd	23-Jul-98	27 Beraking		SF	3	Very open wandoo woodland with grass trees.			-32.0600	116.3867
8	Manaring Lake	23-Jul-98	23 Chidlow	Y	SF	3003	Marri and shrubs at the margin of a drying lake	0		-31.8750	116.3250
9	Gingagup Brook Scarp	29-Jul-98	30 Jarrahdale		SF	3	Jarrah on granitic outcropping of the Darling Scarp.	4	NW	-32.3150	116.0350
10	Karnet Brook	29-Jul-98	30 Jarrahdale		SF	3	Dense jarrah in a creek line with very deep litter and smooth barked gums next to creek.	4	SW	-32.4070	116.0270
11	Scarp Rd	29-Jul-98	35 Dwellingup		SF	3	Jarrah and marri forest with banksias and grasstrees	2	SW	-32.5600	116.0050
12	Wellington Mill	30-Jul-98	51 Burekup	Y	SF	1184	Jarrah with very thick understorey sloping forest to creek.	4	SW	-33.4430	115.9080
13	Mt. Leona Rd	30-Jul-98	51 Burekup		SF	3	Jarrah and marri forest with banksias and grass trees.	2	SW	-33.3920	115.8870
14	Mt. Leona Rd (Collie River)	30-Jul-98	51 Burekup		SF	1185	Jarrah, peppermints and large river gums in deep river valley.	0		-33.3620	115.9030
15	Namming NR	06-Aug-98	7 Yatheroo	Y	NR	1026	Banksias and acacia sandplain shrubland.	2	SW	-30.8560	115.5880
16	Watheroo NP	06-Aug-98	2 Tanche		NP	1036	Banksia woodland.	1	W	-30.3200	115.7917
17	Nilgen NR	07-Aug-98	6 Walyengarra	Y	NR	1026	Coastal dune scrub principally with acacias.	V		-30.9730	115.3200
18	Wedge Island Dune	07-Aug-98	6 Walyengarra	Y	VCL	1026	Coastal dune scrub principally with acacias and sheoaks.	4	E	-30.8410	115.2320
19	Nilgen NR (Tukey Track)	07-Aug-98	6 Walyengarra	Y	NR	1026	Coastal dune heathland with occasional large tuart.	3	E	-30.8730	115.3070
20	South Mimmegarra NR	08-Aug-98	7 Yatheroo		NR	1030	Banksia woodland.	0		-30.9783	115.5200
21	Mission Lake	08-Aug-98	10 Bidaminna	Y	NP	949	Banksia woodland in wet sandplain depression. Melaleucas at lake edge.	3/4	S	-31.0667	115.6217
22	Chittering Lake NR	08-Aug-98	15 Chittering		NR	973	Woodland at lake margin with mainly Melaleucas and smooth-barked gums.	3	SW	-31.4180	116.0930

Site	Name	Date	Locality		BF	Tenure	Veg	Site Description	Slope	Aspect	Latitude	Longitude
23	John Forest NP (Jane Brook)	11-Aug-98	22	Mundaring	Y	NP	2003	Marri with grasstrees, shrubs and granite outcrop with mosses.	2	SSW	-31.8850	116.0900
24	John Forest NP (Scarp)	11-Aug-98	22	Mundaring	Y	NP	2003	Jarrah and wandoo on granitic outcropping of the Darling Scarp.	V		-31.8900	116.0870
25	Warren NP (Petticoat Lane at river)	13-Aug-98	96	Meerup		NP	1144	Karri forest next to Warren River with hazel, marri, peppermint and sheoaks.	3/4	SW	-34.5070	115.9130
26	Warren NP (Trean Brook)	13-Aug-98	88	Charnwood		NP	1144	Karri forest with hazel and sheoaks.	2/3	N	-34.4820	115.9250
27	D'Entrecasteaux NP (Quinerup Spring)	14-Aug-98	87	Lake Jasper	Y	PP?	1109	Peppermint and banksia woodland with dense shrubs, mosses and creepers.	0		-34.4420	115.6850
28	Cleave Rd off Scott Rd	14-Aug-98	88	Charnwood		SF	3	Jarrah and marri forest slope leading to almost dry gully.	3	NE	-34.4180	115.7930
29	Big Brook Dam	15-Aug-98	89	Pemberton		SF	1	Karri forest with very dense understorey.	2	E	-34.4050	116.0270
30	Yornup Block (Upper Donnelley River)	15-Aug-98	80	Wilgarup		SF	27	Jarrah, marri and banksia forest with grasstrees.	3	E	-34.0980	116.1580
31	Walyunga NP	21-Aug-98	19	Jumperkine		NP	4	Very steep sided gully in granite rocks with sparse flooded gums.	5	E	-31.7320	116.0730
32	Canning River (Below Canning Dam)	25-Aug-98	26	Kelmscott		SF	3	Jarrah, marri and flooded gum in gully with significant granite outcropping.	4/5	N	-32.1430	116.1100
33	Dryandra (Lions Village)	07-Sep-98	43	Congelin		SF	5	Wandoo woodland and mallet plantations with many laterite breakaways.	0		-32.7870	116.9820
34	Yeal Swamp NR	01-Oct-98	14	Gingin		NR	1014	Melaleucas in swamp surrounded by Banksia woodland with occasional marri.	1	SW	-31.4700	115.7620
35	Jam Hill NR	02-Oct-98	5	Lake Dalaroo	Y	NR	999	Acacias dominated sloping upland heath with occasional stunted jarrah on lower slopes.	3	S	-30.6860	115.8020
36	Bundarra NR	04-Oct-98	8	Capitela		NR	1015	Wandoo woodland with laterite breakaway.	3	W	-30.9250	115.8250
37	Pinjar Power Station	06-Oct-98	18	Muchea		VCL	965	Sandplain banksia woodland with occasional marri.	0		-31.5560	115.8600
38	Boonanaring NR (1)	07-Oct-98	11	Mindarra		NR	949	Sparse jarrah and heath on sand. Recently burned	0		-31.2100	115.9030
39	Boonanaring NR (2)	07-Oct-98	11	Mindarra		NR	1027	Jarrah forest with grasstrees on a laterite ridge. Very recently burned.	2	N	-31.2330	115.9070
40	Boonanaring NR (3)	07-Oct-98	11	Mindarra		NR	1027	Melaleucas with some jarrah and marri in dry creek bed.	0		-31.2500	115.9100
41	Bindoon Spring	09-Oct-98	16	Dewars Pool		SF	4	Wandoo woodland with grasstrees in depression.	V		-31.4080	116.3670
42	Julimar CP	09-Oct-98	16	Dewars Pool		NR	968	Wandoo woodland surrounding shallow creek line with grasstrees and macrozamia cycads. Soil wet in places.	1/2	NW	-31.3950	116.2950
43	Moganmoganning NR	11-Oct-98	26	Kelmscott		NR	4	Wandoo woodland with damp area/creek bed.	1	SW	-31.1200	116.2530
44	Seven Mile Well NR	11-Oct-98	12	Wannamal		NR	4	Sparse wandoo with sheoak and heath. Many stones (dolerite?) on breakaway.	3	E	-31.0650	116.2020
45	Wannamal Lakes NR	11-Oct-98	12	Wannamal		NR	4	Marri, wandoo, melaleucas and sheoak at lake edge.	0		-31.0750	116.0470
46	Yanchep NP	13-Oct-98	17	Yanchep		NR	1011	Tuart forest next to lake with outcropping limestone and dense understorey of acacias and creepers.	4	SE	-31.5200	115.6630
47	Salt Lake (North of Jurien Bay)	14-Oct-98	1	Hill River	Y	?	129	Salt lake margin with saltbush and other samphire plants.	0		-30.1880	115.0200
48	Drovers Cave NP	14-Oct-98	1	Hill River		NP	1029	Acacia thicket on limestone with grasses near cave	4	S	-30.2530	115.0870

Site	Name	Date	Locality		BF	Tenure	Veg	Site Description	Slope	Aspect	Latitude	Longitude
49	Hill River NP	14-Oct-98	1	Hill River		NP	1028	Melaleucas and smooth-barked gums in riparian zone.	0		-30.3030	115.1830
50	Nambung NP	15-Oct-98	3	Cervantes	Y	NP	1029	Tuarts, acacias and other shrubs and creepers in interdunal sand heath.	3	W	-30.5420	115.1430
51	Wongonderrah NR	15-Oct-98	4	Wongonderrah		NR	1030	Drying Melaleuca swamp with grass trees and banksias.	0		-30.5600	115.3580
52	Nambung NP (Pinnacles)	15-Oct-98	3	Cervantes		NP	129	Sand with limestone pinnacles and acacia shrubs.	0		-30.6050	115.1600
53	Nambung NP (Lake Thetis)	16-Oct-98	3	Cervantes		NP	1026	Sedges and acacia scrub at edge of small coastal salt lake.	0		-30.5070	115.0820
54	Moore River State Forest	16-Oct-98	9	Lancelin		SF	949	Banksia woodland and pine plantation.	3	W	-31.1400	115.4750
55	Moore River North Bank	18-Oct-98	13	Moore River		RR	1007	Tuart woodland with many limestone rocks adjacent to north bank of Moore River.	5	S	-31.3530	115.5020
56	Mooliabeenee Rd (C42743)	18-Oct-98	14	Gingin		NR?	1027	Dry open jarrah and marri woodland with much Dryandra sessilis.	3/4	NW	-31.3480	115.9950
57	Mount Byroomanning Nr	18-Oct-98	15	Chittering		NR	4	Gully and granite outcrop with wandoo and dense shrubby understorey.	3	W	-31.3730	116.1270
58	Clackline NR	20-Oct-98	20	Toodyay	Y	NR	4	Wandoo woodland with dry creek, grasstrees and occasional marri.	2	S	-31.7000	116.4830
59	Wambyn NR	21-Oct-98	24	Mount Observation	Y	NR	4	Wandoo woodland and laterite ridge.	3	N	-31.8980	116.6350
60	St. Ronan's Well NR	21-Oct-98	24	Mount Observation		NR	4	Wandoo woodland with a granite outcrop and pockets of marri and sheoak.	2	SW	-31.8730	116.6400
61	Mokine NR	21-Oct-98	31	Yaganing		NR	352	Wandoo woodland with laterite breakaway with acacias and grasses.	2/3	SE	-31.7970	116.5930
62	Wandoo CP	22-Oct-98	28	Coolaring		NR	4	Wandoo woodland with laterite breakaway and granite outcropping.	1/2	NW	-32.0520	116.5450
63	Dabbaberry NR	22-Oct-98	28	Coolaring		NR	1003	Wandoo woodland and grasstrees on sandy soil.	1	S	-32.2070	116.5700
64	Lupton CP North	26-Oct-98	32	Luptons		CP	1003	Wandoo woodland with some jarrah and marri.	2	S	-32.4470	116.6430
65	Strange Rd NR	26-Oct-98	32	Luptons		NR	1003	Marri, jarrah and sheoak wooodland	2	W	-32.4030	116.6150
66	Flint Block Boyagarring/Colin Rd	26-Oct-98	32	Luptons		SF	3	Wandoo woodland with macrozamia cycads	2	SE	-32.2970	116.5430
67	Lupton CP South	28-Oct-98	37	Wandering	Y	CP	1003	Wandoo woodland with some marri and a granite outcrop in a gully.	2	E	-32.5570	116.6930
68	Moorapulling NR	28-Oct-98	42	Dwarda		NR	3	Jarrah and marri forest with grasstrees.	1	SE	-32.9020	116.5730
69	Hillman NR	28-Oct-98	55	Hillman		NR	4	Wandoo woodland, flat and waterlogged in places, with patches of dense shrubs.	0		-33.3170	116.8070
70	Jingalup NR	29-Oct-98	84	Uannup	Y	NR	4	Jarrah, marri and wandoo woodland.	3	S	-34.0130	117.0130
71	Narlingup NR	29-Oct-98	73	Qualeup	Y	NR	4	Wandoo woodland with acacia shrubs and grasses. With a flowing salty creek and small salt pans.	0		-33.8630	116.8900
72	Haddleton NR	29-Oct-98	63	Blackwood River		NR	3	Jarrah woodland in a sandy depression with marri, banksias, grasstrees and a small granite outcrop.	2/3	S	-33.6330	116.5980
73	Boolading NR	30-Oct-98	54	Darkan		NR	3	Wandoo and jarrah woodland with some shrubs and occasional laterite exposed.	3	E	-33.3500	116.6270
74	Proposed Lane Poole Extension	30-Oct-98	47	Nalyerin		SF	3	Jarrah woodland with sheoaks, some wandoo and marri.	1	NW	-33.2030	116.4630

Site	Name	Date	Locality	BF	Tenure	Veg	Site Description	Slope	Aspect	Latitude	Longitude
75	Harris Dam SF	30-Oct-98	52 Collie	Y	SF	3	Jarrah forest near creek. Specimens found only in very small, unburned island. Surrounding area extensively burned.	3	SE	-33.2550	116.1150
76	Occidental Forest Block (Dale Rd)	04-Nov-98	27 Beraking		SF	3	Jarrah forest with extensive patches of sheoak and some grasstrees.	2	W	-32.1050	116.2570
77	Monadnocks CP (Marginata Rd)	04-Nov-98	112 Oyster Harbour		CP	3	Gentle gully in jarrah forest with marri and grasstrees. Extensive but patchy litter build up.	2/3	SW	-32.2420	116.2050
78	Monadnocks (Millar's Log Rd)	05-Nov-98	78 Jalbarrgup		SF	3	Very sparse and dry jarrah forest with a lot of exposed laterite, very rocky with some banksias.	2/3	NW	-32.3950	116.3350
79	Schulstaad Rd Creek	05-Nov-98	31 Yaganing		SF	3	Jarrah and wandoo woodland with grasstrees, exposed laterite and a creek almost dry.	0		-32.2800	116.3600
80	Ken Rd State Forest	06-Nov-98	36 Duncan		SF	3	Recently burned jarrah and banksia forest with zamias. Evidence of logging very patchy litter.	3	S	-32.5320	116.2850
81	White Horse Hill	06-Nov-98	36 Duncan		SF	3	Jarrah forest with banksias, zamias with exposed laterite. Extensive laterite ridge to south.	2/3	E	-32.6070	116.2950
82	Amphion Forest Block	10-Nov-98	40 Nanga		SF	3	Very long unburned jarrah forest with banksia, zamias and grasstrees.	2	S	-32.7920	116.1870
83	Lepers Gully Rd	10-Nov-98	40 Nanga	Y	CP	3	Deep gully in jarrah forest with zamias, grasstrees ferns, hazel. Creek flowing.	3	S	-32.8470	116.1080
84	Hotham River (Upper Slopes)	11-Nov-98	41 Marradong		SF	3	Jarrah and grasstrees on lateritic slope. Very little litter.	3	SW	-32.9170	116.3820
85	Murray River (CP)	11-Nov-98	41 Marradong	Y	CP	3	Jarrah, flooded gum grasstrees and many shrubs next to granite outcrop.	4/5	SW	-32.9700	116.3020
86	Pindalup Rd/ N.E. Rd	11-Nov-98	35 Dwellingup		SF	3	Jarrah and Marri forest with zamias and bracken fern. Logging operations all around.	2	NE	-32.6000	116.2000
87	Buller NR	12-Nov-98	39 Hamel		NR	1000	Banksia and sheoak woodland on sandplain with occasional jarrah. Notable build up of Casuarina litter.	0		-32.8770	115.8300
88	Austin Bay NR	12-Nov-98	34 Pinjarra		NR	27	Littoral sheoak estuary lagoon. Isopods extremely abundant under littoral samphire vegetation.	0		-32.6380	115.7720
89	Yalgorup NP	13-Nov-98	38 Lake Clifton		NP	998	Peppermint and tuart forest with paperbarks at edge of coastal salt lake.	0		-32.9130	115.6830
90	Batalling SF	23-Nov-98	53 Muja		SF	3	Sparse jarrah forest with sheoak, grasstrees. Patches of laterite and sand.	1	N	-33.3330	116.4730
91	Noggerup CP	24-Nov-98	61 Wilga		CP	3	Jarrah and marri forest with grasstrees, Flat with intermittent laterite patches.	0		-33.6220	116.1230
92	Preston CP	24-Nov-98	61 Wilga	Y	CP	1184	Virgin jarrah forest with sparse understorey of mainly zamias and bracken fern. Sloping away steeply to SE.	3	SE	-33.6030	116.0630
93	Ludlow Tuart Forest NP	25-Nov-98	58 Busselton		NP	2	Tuart and peppermint forest on sandy soil with zamias and grassy understorey.	0		-33.6150	115.4670
94	Leschenault CP	25-Nov-98	44 Lake Preston		CP	48	Peppermint woodland with some tuarts next to reedy margin of estuary. Limestone frequent among litter.	3/4	E	-33.2250	115.6920
95	Benger Swamp NR	25-Nov-98	45 Harvey		NR	968	Isolated melaleuca swamp heavily modified by earthworks.	0		-33.1780	115.8330
96	Chalk Brook	26-Nov-98	46 Tallanalla	Y	CP	3	Sparse jarrah forest with grasstrees and tall shrubs along creek line.	4	SW	-33.0670	116.2320
97	Falls Creek NR	26-Nov-98	46 Tallanalla		NR	3	Recently burned jarrah and marri forest with fallen trees but virtually no litter.	2	SW	-33.0650	116.0150
98	Joes Rd	30-Nov-98	60 Donnybrook		SF	3	Jarrah and marri forest with grasstrees. Evidence of wells and other disused infrastructure.	0		-33.7300	115.7530
99	Claymore Rd (Happy Valley)	30-Nov-98	59 Capel	Y	SF	1185	Very dry jarrah and marri forest with dry creek at site.	2	S	-33.7020	115.6030
100	Bridgetown West NR	01-Dec-98	70 Bridgetown		NR	3	Jarrah and marri, forest with banksia and grasstrees. Small, isolated remnant reserve.	2	SE	-33.9520	116.0780

Site	Name	Date	Locality	BF	Tenure	Veg	Site Description	Slope	Aspect	Latitude	Longitude
101	Bridgetown Jarrah Park	01-Dec-98	79 Carlotta Brook		CP	3	Tall jarrah and marri forest with banksias and a dense understorey. Some extremely large stumps.	2/3	N	-34.0300	115.9830
102	Milyeannup CP	02-Dec-98	12 Jalbarrgup		CP	1183	Jarrah, flooded gum and peppermint riparian forest.	4	NW	-34.0900	115.5670
103	St Johns CP	02-Dec-98	68 Cambray		CP	1183	Steep jarrah and marri forest with acacias in understorey.	4	SW	-33.9450	115.6900
104	Ellis Creek Rd	03-Dec-98	69 Ballingup	Y	SF	3	Jarrah and marri forest with some karri nearby. Recently burned on other side of the road	2	SW	-33.9350	115.8820
105	Mullalyup CP	03-Dec-98	60 Donnybrook		CP	3	Jarrah and marri forest with mainly acacias in understorey.	0		-33.7150	115.8680
106	Burnside Rd NR	03-Dec-98	34 Pinjarra		NR	3	Jarrah and marri woodland with grass tress at foot of Darling Scarp.	0		-32.7230	115.9430
107	Yelverton State Forest	07-Dec-98	57 Yallingup		SF	1181	Sparse jarrah and marri woodland on sandy soil with prickly shrubs and occasional grasstrees.	0		-33.7380	115.1020
108	Leeuwin-Naturaliste NP (Quininup Karri)	07-Dec-98	57 Yallingup		NP	23	Karri and marri forest on steeply sloping near coastal site with peppermints, zamias and bracken fern.	3	SW	-33.7350	115.0070
109	Rapids CP	08-Dec-98	67 Whicher		CP	3	Jarrah and marri forest near pool on upper Margaret River.	0		-33.8770	115.2880
110	Spearwood Creek	08-Dec-98	77 Rosa		SF	3	Riparian forest with flooded gums, peppermints, grasstrees and some marri.	V		-34.0920	115.3130
111	Scott River NP	09-Dec-98	85 Leeuwin		NP	23	Eucalypt, peppermint and banksia low woodland on sand flat with zamia cycads and grasstrees.	0		-34.3030	115.1730
112	Gingilup Swamps NR	09-Dec-98	86 White Point		NR	22	Long unburned, dense jarrah, marri, peppermint woodland with zamias, logs and very deep litter.	1	S	-34.3320	115.4400
113	Leeuwin-Naturaliste NP (Hamelin Bay)	10-Dec-98	76 Karridale		NP	1108	Coastal dune shrubland on primary dune dominated by dwarf peppermint.	V	N	-34.2070	115.0380
114	Leeuwin-Naturaliste NP (Hamelin karri)	10-Dec-98	76 Karridale	Y	NP	1	Karri and peppermint forest on sandy slope with limestone	3	NE	-34.2000	115.0720
115	Margaret River Creek	10-Dec-98	66 Cowaramup		SF	1	Karri forest with hazel, peppermint and some pines.	4	SW	-33.9350	115.0650
116	Porongorup NP (Bolganup)	16-Dec-98	104 Porongurup		NP	1	Karri and marri forest with tall shrubs and maidenhair ferns.	2	NE	-34.6700	117.8820
117	Porongorup NP (Wansbrough)	16-Dec-98	104 Porongurup	Y	NP	1	Karri and marri forest on steep slope with hazel and many granite outcrops.	4	SW	-34.6830	117.8480
118	Marbelup NR	17-Dec-98	111 Redmond		NR	978	Casuarina and marri woodland on laterite.	3	W	-34.9920	117.7220
119	West Cape Howe NP	17-Dec-98	119 Torbay	Y	NP	14	Karri and marri coastal forest with peppermints.	V		-35.0820	117.6430
120	Millbrook NR	18-Dec-98	10 Bidaminna		NR	978	Stunted marri woodland with melaleucas in gully. Very dry with lots of laterite.	2	W	-34.8550	117.8470
121	Torndirrup NP	18-Dec-98	120 Albany	Y	NP	49	Very low coastal woodland on coastal dune sand with stunted eucalypts and banksia	2	NE	-35.1150	117.9330
122	Waychinicup NP	19-Dec-98	114 Mount Manypeaks		NP	989	Isolated patch of woodland Next to a creek and granite outcrop surrounded by coastal heath.	0		-34.8800	118.3270
123	Two Peoples Bay NR	19-Dec-98	113 Two Peoples Bay	Y	NR	423	Low coastal woodland with banksias peppermints, sheoaks and sedges.	2	SW	-34.9770	118.1820
124	Down Rd NR	20-Dec-98	112 Oyster Harbour		NR	978	Jarrah and marri woodland on a sandy slope with abundant casuarinas.	2	S	-34.9550	117.7580
125	Pardelup NR	20-Dec-98	102 Kwornicup		NR	3	Jarrah marri forest with paperbarks in a gully.	2	SE	-34.6720	117.4150
126	Walpole Nornalup NP (Tinglewood)	07-Jan-99	108 Mount Frankland	Y	NP	1139	Tall forest of karri and tingle with sedges and soft leaved shrubby understorey.	4	SW	-35.0030	116.6380

Site	Name	Date	Locality	BF	Tenure	Veg	Site Description	Slope	Aspect	Latitude	Longitude
127	William Bay NP	07-Jan-99	117 Parry Inlet	Y	NP	423	Peppermint woodland on sandy soil with occasional low shrubs and sedges.	4		-35.0020	117.2280
128	Denbarker Block (Stan Rd)	08-Jan-99	110 Denmark		SF	3	Jarrah and marri forest with tall shrubby understorey. Recently burned on one side of the road.	0		-34.8250	117.3470
129	Mt Lindesay (West Side)	08-Jan-99	110 Denmark		NP	977	Jarrah, marri and sheoak forest on sandy soil with some laterite and some very large banksias.	2	S	-34.8630	117.3180
130	Rate Block	09-Jan-99	109 Owingup		NP	1	Karri and sheoak forest with a very dense shrubby understorey with creepers.	1	SW	-34.8350	117.0070
131	Willmott Block	09-Jan-99	100 Mount Roe		VCL	3	Jarrah marri and banksia forest on a sandy soil with occasional laterite.	1	SE	-34.6520	116.9600
132	Clear Hills/Watershed Rd	09-Jan-99	101 Rocky Gully		SF	14	Jarrah and marri forest on a laterite flat with grasstrees.	0		-34.6980	117.1820
133	Ordnance State Forest	10-Jan-99	107 Deep River	Y	SF	27	Tall marri forest with some karri.	2	N	-34.8680	116.6650
134	Mount Frankland NP (Crossing Block)	10-Jan-99	108 Mount Frankland	Y	NP	27	Jarrah, marri forest with some banksias on flat lateritic terrain and a dense shrubby understorey.	0		-34.8030	116.8830
135	Walpole Nornalup NP	11-Jan-99	115 Saddle Island	Y	NP	1150	Karri and tingle forest with peppermint and hazel.	2	SW	-34.9880	116.7600
136	Long/Thompson Block	11-Jan-99	99 Mount Johnston	Y	SF	1	Jarrah and marri forest on a gravelly lateritic slope.	3	SE	-34.6600	116.7030
137	Kingston Rd	24-Jan-99	81 Yerraminnup		SF	3	Jarrah, marri and banksia forest on laterite soils with occasional sandy patches and with zamias	1	NE	-34.0850	116.3500
138	Warren River/Deeside Coast Rd.	24-Jan-99	90 Deeside		SF	1144	Jarrah and banksia forest with flooded gum adjacent to river and tall shrubby understorey.	2	SW	-34.3920	116.4030
139	Warrup Block	25-Jan-99	81 Yerraminnup	Y	SF	3	Jarrah and marri forest with banksias and grasstrees. According to CALM last burned in 1975.	1	NE	-34.1480	116.3320
140	Perup NR	25-Jan-99	82 Tonebridge		NR	3	Open jarrah and marri with zamias on a lateritic and sandy soil.	1		-34.1530	116.6070
141	De Landgrafft Rd	26-Jan-99	91 Lake Muir		SF	3	Jarrah and marri with zamias on a lateritic soil. According to CALM, last burned 1971/2 and a no planned burn area.	1/2		-34.2670	116.5920
142	Lake Unicup NR	26-Jan-99	91 Lake Muir	Y	NP	3	Jarrah and marri woodland on sandy soil with grasstrees and zamias.	0		-34.3680	116.7000
143	Shannon NP (Fish Creek Rd.)	27-Jan-99	98 Shannon		NP	1	Tall karri and sheoak forest with patches dense reeds in understorey and tiger snakes!	3		-34.6250	116.4370
144	Shannon River/Chesapeake Rd.	27-Jan-99	106 Wainbup		NP	1144	Riparian karri forest with small peppermints and reeds in the understorey.	0		-34.8420	116.3700
145	Bombakup State Forest	28-Jan-99	97 Northcliffe	Y	SF	1002	Riparian karri forest with peppermints and reeds and much debris in creek bed.	V		-34.6080	116.0320
146	Mt. Chudalup	28-Jan-99	105 Gardner River		SF	1144	Karri and marri forest with peppermints at base of a large granite outcrop.	3		-34.7630	116.0830
147	Harvey River (Quindanning Rd) **	26-Nov-98	45 Harvey	Y	RR	1184	Berlese funnel sample only. Taken here instead of site 97 which was selected for litter collection but had no litter.	-		-33.0830	115.9830
148	Walpole Nornalup NP (Sapper's Bridge) **	10-Jan-99	108 Mount Frankland	Y	NP	1150	Became too dark to search reliably so Berlese funnel sample taken.	-		-34.9600	116.8220

Abbreviations: NP = National Park; NR = Nature Reserve (Gazetted reserve); PP = Private Property; CP= Conservation Park (Management reserve); SF = State Forest (Multiple-use forest); RR = Road/River Reserve; VCL = Vacant Crown Land.

* These sites were not sampled by standard methods and have no accompanying microhabitat data. ** These sites were Berlese funnels only.

Appendix 1b.
Description of vegetation associations (from Beard,1981b) for sites where vegetation codes were given Appendix 1a

Code	Beard's Code	Vegetation Association Description from Beard (1981b)
1	e1Tc	Tall forest; karri (Eucalyptus diversicolor)
2	e4Ti	Tall woodland; tuart (Eucalyptus gomphocephala)
3	e2,3Mc	Medium forest; jarrah-marri
4	e3,5Mi	Medium woodland; marri & wandoo
5	e5,45Mi	Medium woodland; wandoo & powderbark (Eucalyptus accedens)
14	e2Lc	Low forest; jarrah
22	agLi	Low woodland; Agonis flexuosa
23	e2bLi	Low woodland; jarrah-banksia
27	mLi	Low woodland; paperbark (Melaleuca sp.)
48	xSZc	Shrublands; scrub-heath
49	xZc	Shrublands; mixed heath
129	ds	Bare areas; drift sand
352	e6Mi	Medium woodland; York gum
423	aSZc	Shrublands; Acacia scrub-heath (unknown spp.)
949	bLi	Low woodland; banksia
965	e2,3Mi	Medium woodland; jarrah & marri
968	e2,3,5Mi	Medium woodland; jarrah, marri & wandoo
973	mLc	Low forest; paperbark (Melaleuca rhaphiophylla)
977	mcLc	Low forest; teatree & casuarinas
978	e2,65,c7Lc	Low forest; jarrah, Eucalyptus staeri & Allocasuarina fraseriana
989	e65SZc	Shrublands; Albany blackbutt mallee-heath
998	e4Mi	Medium woodland; tuart
999	e3Mi	Medium woodland; marri
1000	e2,3Mi/bLi/mLc	Mosaic: Medium forest; jarrah-marri / Low woodland; banksia / Low forest; teatree (Melaleuca spp.)
1002	e2Mr	Medium open woodland; jarrah
1003	e2,3,5Mc	Medium forest; jarrah, marri & wandoo
1007	unknown	Shrublands; coastal heath and thicket
1011	e4Mr	Medium open woodland; tuart
1014	bLi/mSc	Mosaic: Low woodland; banksia / Shrublands; teatree thicket
1015	x14SZc/dZc	Mosaic: Shrublands; scrub-heath on the Swan Coastal Plain / Shrublands; Dryandra sp. heath
1026	a23,32m3Sc/a26m4Zc	Mosaic: Shrublands; Acacia rostellifera, A. cyclops (in the south) & Melaleuca cardiophylla (in the north) thicket / Shrublands; Acacia lasiocarpa & Melaleuca acerosa heath
1027	e2,3Mr bLi/e2,3,Mp	Medium open-sparse woodland; jarrah & marri, with low woodland; banksia
1028	e18Mi	Medium woodland; river gum
1029	x9SZc	Shrublands; scrub-heath dryandra-calothamnus association with Banksia prionotes on limestone in the northern Swan Region
1030	b1,2Li	Low woodland; Banksia attenuata & B. menziesii
1036	b3Li	Low woodland; Banksia prionotes
1108	a31Sc	Shrublands; Acacia decipiens scrub
1109	agSi	Shrublands; peppermint scrub, Agonis flexuosa
1139	e1,74Tc	Tall forest; karri & yellow tingle (Eucalyptus guilfoyleii)
1144	e1,3Tc	Tall forest; karri & marri (Corymbia calophylla)
1150	e1,68,74Tc	Tall forest; karri, red tingle & yellow tingle
1180	chSc	Shrublands; Calothamnus quadrifidis & Hakea trifircata scrub (Cape Naturaliste)
1181	e2,63Mi	Medium woodland, jarrah & Eucalyptus haematoxylon (Whicher Range)
1183	e18,72Mi	Medium woodland; Eucalyptus rudis & blackbutt with some bullich, jarrah & marri (fringing Blackwood River)
1184	e2,3,18,agMi	Medium woodland-fringing; jarrah, marri, Eucalyptus rudis & Agonis flexuosa
1185	e2,3,72Mi	Medium woodland; jarrah, marri & blackbutt

APPENDIX 2.

TABLE OF RAW DATA

Appendix 2

The nature of the records and microhabitat utilisation of the indigenous taxa, and the page number where the list of material examined can be found. Data in the upper row of each taxon are actual numbers and those in the lower rows are percentages for each of the categories given in first line of the table.

Taxonomy		Biogeography		Nature of Records				Generic Category (with data)					Microhabitat detail for records with data (Codes defined in Table 4.2)																											
# Taxon	Material Examined	Pattern	Scale	n	No Data	Pitfall Traps	With data	Litter	Logs	Bark	Rocks	Other	L10	L20	L30	L40	L41	L42	L50	L60	L70	L80	L90	G10	G20	G30	G40	B10	B20	B30	B40	R1	R2	R3	R4	R5	S1	A1-3 U1	
12 Notoniscus new species	p. 151	High Rainfall	RD	4	2 50	-	2 50	1 50	-	1 50	-	-	-	-	-	-	1 50	-	-	-	-	-	-	-	-	-	1 50	-	-	-	-	-	-	-	-	-	-	-	
13 Styloniscus species 1 (Other)	p. 154	Forest	SR	186	9 4.8	43 23.1	134 72.0	71 53.0	60 45.5	1 0.7	1 0.7	1 0.7	42 31.3	16 11.9	7 5.2	2 1.5	- -	4 3.0	-	-	-	-	-	48 35.8	6 4.5	2 1.5	4 3.0	-	-	-	1 0.7	1 0.7	-	-	-	-	1 0.7	-	
13 Styloniscus species 1 (Warren Bioregion)	p. 154	Forest	LO	57	18 31.6	0 0	39 68.4	28 71.8	8 20.6	3 7.7	0 0	0 0	15 38.5	4 10.3	-	3 7.7	5 12.8	-	-	1 2.6	-	-	-	-	4 10.3	3 7.7	1 2.6	2 5.1	-	-	1 2.6	-	-	-	-	-	-	-	
13 Styloniscus species 1 (All)	p. 154	Forest	SR	243	27 11.1	43 17.7	173 71.2	99 57.2	68 39.3	4 2.3	1 0.6	1 0.6	57 32.9	20 11.6	7 4.0	5 2.9	5 2.9	4 2.3	-	1 0.6	-	-	-	48 27.7	10 5.8	5 2.9	5 2.9	2 1.2	-	-	2 1.2	1 0.6	-	-	-	-	1 0.6	-	
14 Styloniscus species 2	p. 157	Eastern	LO	3	-	-	3 100	1 33.3	1 33.3	-	1 33.3	-	-	-	-	-	-	1 33.3	-	-	-	-	-	-	-	1 33.3	-	-	-	-	-	1 33.3	-	-	-	-	-	-	
15 Styloniscus species 3	p. 158	High Rainfall	LO	6	3 50	-	3 50	3 100	-	-	-	-	3 100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
16 Styloniscus species 4	p. 159	Single Locality	SL	1	-	-	1 100	1 100	-	-	-	-	1 100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
17 Styloniscus species 5	p. 160	Single Locality	SL	1	-	-	1 100	1 100	-	-	-	-	1 100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
18 Styloniscus species 6	p. 161	High Rainfall	SR	2	-	-	2 100	-	2 100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1 50	1 50	-	-	-	-	-	-	-	-	-	-	-	-	
19 Styloniscus species 7 (Other)	p. 162	Forest	SR	43	8 18.6	5 11.6	30 69.8	21 70.0	6 20.0	2 6.7	1 3.3	0 0	13 43.3	3 10.0	-	1 3.3	3 10.0	1 3.3	-	-	-	-	-	1 3.3	3 10.0	-	2 6.7	1 3.3	-	-	1 3.3	1 3.3	-	-	-	-	-	-	
19 Styloniscus species 7 (Warren Bioregion)	p. 162	Forest	SR	76	21 27.6	6 7.9	49 64.5	22 44.9	17 34.7	7 14.9	1 2.0	2 4.1	11 22.4	4 8.2	-	-	4 8.2	-	-	1 2.0	-	2 4.1	-	-	10 20.4	2 4.1	5 10.2	6 12.2	-	-	1 2.0	-	1 2.0	-	-	-	1 2.0	1 2.0	
19 Styloniscus species 7 (All)	p. 162	Forest	SR	119	29 24.4	11 9.2	79 66.4	43 54.4	23 29.1	9 11.4	2 2.5	2 2.5	24 30.4	7 8.9	-	1 1.3	7 8.9	1 1.3	-	1 1.3	-	2 2.5	-	1 1.3	13 16.5	2 2.5	7 8.9	7 8.9	-	-	2 2.5	1 1.3	1 1.3	-	-	-	1 1.3	1 1.3	
20 Platyarthridae species 1	p. 166	Regional	RL	54	18 33.3	14 25.9	22 40.7	4 18.2	6 27.3	8 36.4	2 9.1	2 9.1	3 13.6	-	-	-	-	1 4.5	-	-	-	-	-	4 18.2	-	-	2 9.1	2 9.1	-	6 27.3	-	1 4.5	1 4.5	-	-	-	2 9.1	-	
21 Platyarthridae species 2	p. 169	Single Locality	SL	1	1 100	-	0 0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
23 Platyarthridae species 3	p. 170	High Rainfall	SR	36	2 5.6	10 27.8	24 66.7	7 29.2	4 16.7	13 54.2	-	-	4 16.7	2 8.3	-	-	1 4.2	-	-	-	-	-	-	-	-	1 4.2	3 12.5	10 41.7	-	-	3 12.5	-	-	-	-	-	-	-	
24 Platyarthridae species 4	p. 172	Northern	LO	4	-	-	4 100	2 50	1 25.0	-	1 25.0	-	2 50	-	-	-	-	-	-	-	-	-	-	-	1 25.0	-	-	-	-	-	1 25.0	-	-	-	-	-	-	
22 Australoniscus springetti	p. 173	Single Locality	SL	16	3 18.8	1 6.3	12 75.0	9 75.0	-	3 25.0	-	-	5 41.7	-	-	-	4 33.3	-	-	-	-	-	-	-	-	-	-	3 25.0	-	-	-	-	-	-	-	-	-	-	

| Taxonomy | | Biogeography | | Nature of Records | | | | Generic Category (with data) | | | | | Microhabitat detail for records with data (Codes defined in Table 4.2) | | | | |

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APPENDIX 3

GLOSSARY

Term	Definition
Record	One or more specimens of a single taxon collected from a specific site on given date. Any differences in microhabitat, collection method and collector or WAM registration number necessitated a new record for a given taxon.
Region	The region is the geographical extent of the southwest of Western Australia is defined by the Darling Botanical District (DBD) (Beard, 1981b) as shown in Figure 1.3. This DND is largely synonymous with the Swan Coastal Plain, the Jarrah Forest and the Warren Bioregions as determined by Thackway and Cresswell (1995) and shown in Figure 1.4. Sampling in this study was conducted at sites only within the region.
Site	A place with specified latitude and longitude coordinates where specimens were collected as part of this or other study. Study sites sampled during this study are listed in Appendix 1a.
Locality	Southwestern Australia (the region) was divided into 120 localities. Localities represent approximately equal land areas of fifteen minutes latitude by fifteen minutes longitude. They were numbered consecutively in rows from the northwest to the southeast of the region and are shown in Figure 2.1(A). Localities were used a basis for determining sampling sites and for the purposes of biogeographical analysis. They coincide with Australian Topographic Survey 1:50 000 maps and the names of the sheets were used as locality names. Locality names, numbers and reference to maps are given in Table 2.1.
Supplementary Locality	For the purposes of analysis, the study area was extended by three supplementary localities. Locality 200 was added to incorporate records from Rottnest Islands since it fell outside the geographical limit of the localities defined above. Two other supplementary localities, the Stirling Range (201) and Mount Lesueur (202) are known to have high floristic diversity and occur just outside the region. They were included in the dataset since there was significant WAM material that warranted their inclusion. The boundaries of supplementary locality 201 were extended beyond the standard fifteen minutes of longitude to include all material from the Stirling Range National Park.
Landscape Unit (LU)	A composite area derived from a number of adjacent grouped localities. Landscape units (LUS) each encompass approximately the same amount of the study area. Some LUs coincide with areas shown on National Topographic 1:100 000 series maps while some are a combination of two maps. The relevant map names were used to name the LUs. LUs are used only to examine broader scale patterns of taxa richness and diversity within the region.
Zone	A biogeographical region delineated as a result of this study. Zones are identified in Chapter 6 and refined in Chapter 8. They were defined Initially by grouping a number of adjacent localities with similar distributional and diversity characteristics. They were refined by delineating a major faunal break and areas of endemism.